

The McConnell medial taping technique; effects on patellar alignment and pain for  
patellofemoral pain syndrome

by

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## **ABSTRACT**

The effect of the McConnell medial taping technique on patellar alignment and perceived knee pain in patients with patellofemoral pain syndrome (PFPS) between the ages of 20-50 years old was examined in this study. Clinical patellar alignment was assessed with the McConnell and Herrington manual patellar measuring technique while pain measures were assessed using a visual analogue scale (VAS). These measures were collected at three-times during a 4-week treatment protocol: prior to treatment, mid-way treatment and 24 hours after treatment. This study included two therapy groups: one received a standard 4-week therapeutic exercise program for PFPS and the other underwent the same standard 4-week exercise program with the inclusion of McConnell's taping technique. No statistically significant differences were found before and after treatment for pain or patellar alignment in either group. Nonetheless, upon plotting the results a trending decrease in pain for all patients irrespective of group was noted, which raises the question of possible underlying effects influencing pain such as the patellofemoral contact area. Although it appears that the McConnell taping technique had no added benefit when combined with the standard exercise program, this study reaffirms that exercise therapy continues to have a positive effect on PFPS. In conclusion, we speculate that changes in patellofemoral joint (PFJ) contact area may be the primary reason that pain decreases for PFPS patients.

*Keywords:* Patellofemoral Pain Syndrome, Patellar Alignment, McConnell Taping, Osteoarthritis.

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## **LIST OF ABRIVIATIONS**

ADL	Activities of Daily Living
BMI	Body Mass Index
BW	Body Weight
ITB	Iliotibial Band
OA	Osteoarthritis
PFJ	Patellofemoral Joint
PFP	Patellofemoral Pain
PFPS	Patellofemoral Pain Syndrome
VAS	Visual Analogue Scale
VL	Vastus Lateralis Muscle
VMO	Vastus Medialis Oblique Muscle

**CHAPTER I**  
**INTRODUCTION**

## **1.0 Introduction**

“Knees are a major source of pain for millions of people” (Betancourt & Hannafin, 2007, p.xxi). The term “knee pain” includes all anterior pain related problems including the terms: patellar pain and patellofemoral pain syndrome (PFPS) (Thomeé, Augustsson, & Karlsson, 1999; Tumia & Maffulli, 2002). PFPS is known to be the most common cause of pain in the knee (Goldberg, 1997; Powers, 1998; V. Sanchis-Alfonso, Rosello-Sastre, & Martinez-Sanjuan, 1999), affecting 1 in 4 athletes with more than 70% being between 16-25 years of age (Devereaux & Lachmann, 1984). This syndrome emerges within the athletic and non-athletic populations (Frontera, Silver, & Rizzo, Jr., 2014), specifically in adolescents and young adults (V. Baker, Bennell, Stillman, Cowan, & Crossley, 2002; Linschoten et al., 2006; Pappas & Wong-Tom, 2012; Potter & Sequeira, 2014) and has been shown to affect the female population more so than males (Potter & Sequeira, 2014).

Stress, pressure and contact area are very indicative of the knee joint biomechanics. Stress is any stressor that requires the body to change (Muscolino, 2016) (i.e. forces acting on the knee joint that results in cartilage deformation). Pressure is the force applied to a surface and calculated by the reaction force divided by the contact surface (Vicente Sanchis-Alfonso, 2011). In terms of contact area, it is the “total surface area in direct contact at the interface of an articulating joint” (Zdero, 2016, p.253) (i.e. surface area of the patella in contact with the trochlear groove of the femur).

According to a publication by Bonnin et al. (2013) the underlying cause of mechanical joint pain is speculative yet could be induced by three mechanisms including:

increase of intraosseous pressure, irritation of the peripheral nerve endings and the chemical production of different cytokines (Bonnin, Amendola, Bellemans, MacDonald, & Menetrey, 2013). Further, early research has postulated that patella malalignment is the predisposing factor for patellofemoral pain (PFP) (Goodfellow, Hungerford, & Zindel, 1976) and that improper patellar tracking over a long period of time could essentially cause wear and tear of the articular cartilage (Halpern, 2003). Articular cartilage is situated on the surface of load-bearing joints such as behind the patella, and bottom of the femur bone, and helps promote smooth joint movement by distributing compressive forces and reducing friction (Neumann, 2013). Having said this, improper tracking of the patella could lead to cartilage softening, due to a decrease in contact area resulting in greater joint contact stress (Sheehan, Derasari, Brindle, & Alter, 2009) during load-bearing activities. Furthermore, cartilage softening is known to cause chemical synovitis (inflamed and irritated synovial membrane of the joint) (Douciette & Goble, 1992) and progresses to fissure formation, ulceration, and even osteoarthritis (OA) (Fulkerson, 2004). Once the articular cartilage is compromised, other structures within the PFJ can be exposed to non-typical stresses such as the subchondral bone and soft tissues (Biedert & Sanchis-Alfonso, 2002). These structures have peripheral nerve endings (pain receptors), sending pain signals to the brain when innervated. Abnormal tracking of the patella can mechanically irritate the nerve endings and more importantly, cause irreversible nerve damage (Biedert, 2005). Neural damage has been identified with the lateral retinaculum (patellar ligament) in individuals with patellofemoral malalignment (Biedert, 2005; Mori, Fujimoto, Okumo, & Kuroki, 1991; V. Sanchis-Alfonso, Roselló-Sastre, Monteagudo-Castro, & Esquerdo, 1998), raising the concerning effects of patellar maltracking.

As stated above the long-term effects of PFP could result in permanent damage to the knee. Further to this, participation in activities including walking or running can be affected (Crossley, Bennell, Green, Cowan, & McConnell, 2002). Given the various pain tolerances, this syndrome affects everyone differently. According to prior research 74% of individuals with PFPS will limit or end sport participation completely (Blønd & Hansen, 1998; Davis & Powers, 2010; Fairbank, Pynsent, van Poortvliet, & Phillips, 1984; Heintjes et al., 2003). Consequently, this syndrome can ultimately deter one's physical activity level, impacting their overall health.

Pain, if left untreated, has both physiological and psychological consequences as stated by Fine (2011). Fine's conclusions determined that there were some physiological consequences in the literature which included: sleep disturbances, cognitive processes and brain function disruptions (i.e. memory and attention problems) and mood/mental health disorders including depression (Fine, 2011). That being said, pain can negatively impact lifestyle changes. Also identified in Fine's review are the significant economic consequences such as the increased cost of health care and decreased productivity at work (Fine, 2011). Although Fine's review is not specific to that of knee pain, the physiological and economic impacts can certainly be applied. Therefore, it is imperative to research current PFPS treatment procedures to mitigate pain and to minimize the irreversible damage to the knee and the potential negative health outcomes.

Managing PFPS continues to be challenging and remains a common reason for physiotherapy referral (Bolgla & Boling, 2011; Harvie, O'Leary, & Kumar, 2011; Hilyard, 1990; Kettunen et al., 2007). There are a number of treatment options available for PFPS but according to several researchers, the mainstay of intervention for the

syndrome embraces nonoperative treatment particularly exercise therapy (Bolgla & Boling, 2011; Crossley et al., 2002; Gielen & Sleet, 2003; Harvie et al., 2011; Heintjes et al., 2003), incorporating strengthening, stabilizing and stretching exercises (Harvie et al., 2011; Wyss & Patel, 2012). The rationale behind therapeutic treatment is intended to reduce patellofemoral joint (PFJ) pain by enhancing the patellar tracking within the femoral trochlear groove (Aminaka & Gribble, 2005).

Bizzini, Childs, Piva, and Delitto (2003) analysed 20 trials between 1966 and 2000 and discovered that PFPS patients were discharged earlier from physical therapy programs when exercise was included in the intervention. This could be explained by the fact that therapy programs incorporating exercises that target the quadriceps musculature have shown significant reduction in perceived pain (Bily, Trimmel, Mödlin, Kaider, & Kern, 2008; Dursun, Dursun, & Kiliç, 2001; Hazneci, Yildiz, Sekir, Aydin, & Kalyon, 2005; Herrington & Al-Sherhi, 2007). Controlling pain and minimizing loss of function are the main treatment approaches. However, once the pain has been treated, the original cause of the problem should not be disregarded.

Other treatment options that have been proposed for this condition are therapeutic modalities including: neuromuscular electrical stimulation (NMES), transcutaneous electrical nerve stimulation (TENS), electromyography (EMG), biofeedback (Wyss & Patel, 2012) and acupuncture (Näslund, Näslund, Odenbring, & Lundeberg, 2002). Lake and Wofford (2011) researched selected studies where therapeutic modalities were used to treat PFPS. The therapeutic modalities included: cold, ultrasound, phonophoresis, iontophoresis, NMES, TENS, EMG and laser therapy. Twelve studies were included in the review, none of which showed a beneficial effect when a therapeutic modality was



used alone (Lake & Wofford, 2011). They concluded that the effectiveness of therapeutic modalities needs to be combined with another treatment method to benefit the PFP population (Lake & Wofford, 2011). Similarly, researchers Harvie and Kumar (2011) state that the success of treating individuals with PFPS increases once other treatment options such as external patellar supports (i.e. knee bracing and patellar taping) is incorporated with exercise therapy. Furthermore, a recent study conducted in 2015 determined that a patient's PFP prescription should include: education and activity modification, exercise-therapy emphasizing on gluteal and quadriceps strengthening and patellar taping (Barton, Lack, Hemmings, Tufail, & Morrissey, 2015).

Although patellar-taping has become a popular treatment method (Aminaka & Gribble, 2005; Campolo, Babu, Dmochowska, Scariah, & Varughese, 2013; W. Petersen et al., 2014), its general purpose to restore normal patellar tracking (McConnell, 1986) remains speculative. The McConnell medial taping technique is thought to correct patellar alignment by directing the patella medially to promote proper tracking. Hence, the tape is used to assist the patella to track properly which increases the patellofemoral contact area thereby reducing knee joint stress (Warden et al., 2008). In general, a decrease in joint stress would mean PFP patients experience less joint damage and less knee pain. However, the overall change in patella alignment post treatment remains questionable. This current study explores the most common taping technique used in clinical settings with a general purpose to measure the patellar displacement and evaluate the effect of taping on perceived pain within a symptomatic PFP population.

**CHAPTER II**  
**REVIEW OF LITERATURE**

## **2.0 Knee Pain and Patellofemoral Pain Syndrome (PFPS)**

The knee is among one of many mechanically complex joints in the human body (Betancourt & Hannafin, 2007; Long, Rollins, & Smith, 2015; McGinty, Irrgang, & Pezzullo, 2000). The knee articulation consists of two joints: the tibiofemoral joint and the PFJ. The tibiofemoral joint is comprised of the tibia and the femur, whereas the PFJ consist of the patella and the femur. For that reason, PFPS was characterised based on its location within the PFJ.

Interestingly, research has shown that women are more vulnerable to knee pain than men (M. Baker & Juhn, 2000; Betancourt & Hannafin, 2007; Fulkerson & Arendt, 2000). This may be explained by postural (i.e. sitting cross legged) and sociological factors (i.e. wearing high heels), as these factors have been shown to be risk factors of PFPS (Fulkerson & Arendt, 2000). Also, the female pelvis is wider (Grelsamer, Dubey, & Weinstein, 2005) which theoretically can influence the PFJ function, however, uncertainties pertaining to this anatomical difference being a PFP risk factor exist and are further discussed in this review. Additionally, pregnant women have shown cartilage defects at the patellar site (Wei et al., 2012). The authors state that hormonal and lifestyle changes resulting in a decrease of physical activity and weight gain are some key elements explaining gravity's negative influences on the knee (Wei et al., 2012). Moreover, they indicated that the number of births increases the risk of patella cartilage defects, which eventually “may play a direct role in the development of OA” (Wei et al., 2012, p.4). The relationship between knee pain and gender can be further explained by the fact that sex hormones particularly oestrogen has been found in human cartilage,

denoting that cartilage can respond to sex hormones (Richette, Corvol, & Bardin, 2003).

It was determined in a study conducted by Cooper et al. (2000) that repeated knee bending increases chances of knee pain, which helps explain how any population whether it is children, adults or elders could be affected. According to Zaffagnini, Dejour, & Arendt (2010), patellofemoral malalignment and joint loading are the two biomechanical reasons behind knee pain, which are dependant on intensity and duration of physical activity. Furthermore, athletes are known to be more susceptible to traumatic knee pain yet common risk factors associated to this type of pain could also affect the non-athletic population (Betancourt & Hannafin, 2007). These risk factors range from excessive body weight, lack of flexibility and strength and/or a family history of knee pain (Betancourt & Hannafin, 2007). Immobilization as well as repeated intra-articular injection of corticosteroids have also been associated with knee pain (Heng & Haw, 1996). In addition, lower extremity alignment conditions such as genu varum (bowleg) and genu valgum (knock-knee) are significant PFPS risk factors (Messier, Davis, Curl, Lowery, & Pack, 1991; W. Petersen et al., 2014; Wen, Puffer, & Schmalzried, 1998). Although these conditions are naturally seen in growth development of infant and young children, correcting themselves around the age of 7, extrinsic and intrinsic factors could hinder the body's natural growth development (Espandar, Mortazavi, & Baghdadi, 2010). Knee pain thus does not simply occur because of one factor, but rather as a result of many factors (Vicente Sanchis-Alfonso, 2011).

## **2.1 Overweight**

An overweight individual is defined as an individual with a body mass index

(BMI) between 25 and 29.9kg/m<sup>2</sup>, whereas a BMI of 30kg/m<sup>2</sup> is considered obese (Eckel & Krauss, 1998; Heyward, 2010; “WHO | Obesity,” n.d.). According to the World Health Organization, globally there are 300 million adults who are obese and over one billion adults who are overweight (“WHO | Overview,” 2002). A recent study conducted in 2013, researched the adulthood effects of being overweight during childhood (Antony et al., 2013). They found that men in particular who were overweight during their childhood suffered with adulthood knee mechanical joint pain, stiffness and dysfunction (Antony et al., 2013). In fact, overweight children have shown a predisposition to being overweight as an adult (Vos & Welsh, 2010) and as a result a predisposition to knee pain. Further to this, overweight adolescents have a 70% chance of being overweight as adults which could increase to an 80% chance when one or both parents are overweight or obese (American Heart Association, 2008). The global obesity epidemic raises concerns for communities and health care since it is thought to be responsible for disability and a reduced quality of life (Anandacoomarasamy, Caterson, Sambrook, Fransen, & March, 2007).

“Being overweight is one of the leading risk factors for knee pain” (Betancourt & Hannafin, 2007. p.19). The extra weight increases patellar compression forces when performing activities of daily living (ADL), where the amount of compression force on the patella depends on the task. For example: loading on the patella when walking is 0.3 times the body weight (BW) (Magee, 2014). However, the loading increases to 3.5 times the BW when walking down stairs (Betancourt & Hannafin, 2007; J. K. Loudon, Manske, & Reiman, 2013; Magee, 2014), 2.5 times when walking up stairs, and 7 times the BW when squatting (J. K. Loudon et al., 2013; Magee, 2014). For example a person that

weighs 180lbs (801N) would apply 240N to the PFJ while walking ( $0.3 \times 801\text{N} = 240\text{N}$ ). However, assuming 7xBW when squatting, then 5605N would be applied to the joint ( $7 \times 801\text{N} = 5605\text{N}$ ). Therefore, added weight increases mechanical stresses on the knee joint (Teichtahl et al., 2015), and these mechanical stresses are what change the composition, structure, and mechanical properties of the knee articular cartilage (Mündermann, Dyrby, & Andriacchi, 2005).

It is important to consider that mechanical stress is highly related to contact area and consequently could be amplified when the contact area is reduced. For example: a person that weighs 180lbs applies a force of 5605N to the PFJ when squatting. Given a contact area of  $4\text{cm}^2$ , this would apply 14.01MPa of pressure to the joint surface ( $5605\text{N}/0.0004\text{m}^2 = 14.01\text{MPa}$ ), whereas a contact area of  $2\text{cm}^2$  would result in 28.02MPa of pressure ( $5605\text{N}/0.0002\text{m}^2 = 28.02\text{MPa}$ ). It is clear that the evaluation of mechanical stresses on the PFJ requires measurements of contact area (Besier, Draper, Gold, Beaupré, & Delp, 2005). Notwithstanding these examples, it is estimated that normal articular cartilage in the laboratory cannot withstand more than 25MPa of acute contact stress (Heijink et al., 2012; Repo & Finlay, 1977), which is an indication that cartilage damage or degeneration could commence with chronic or repetitive stress  $<25\text{MPa}$  (Buckwalter & Lane, 1997; Vuori, 2001). Though 25MPa is a considerable amount of contact stress, 4-9MPa is the typical amount (in a healthy knee) during normal physical activities that include walking, jumping and throwing (Vuori, 2001). Because already damaged articular cartilage may be present in individuals with PFPS, the contact stress during normal physical activities could be much greater. Farrokhi, Keyak and Powers (2011) compared the PFJ stress in individuals with PFP to pain-free individuals and

found that the symptomatic group had significantly higher joint stresses than the control group with the knee flexed at 15°. The contact area was not recorded in their study, however the indirect relationship between contact area and contact stress affirms that the PFP group exhibited smaller contact areas than the controls. It appears that healthy knees have greater contact area, thus reducing the contact stress across the joint. Above all, being overweight or obese influences the forces and mechanical stresses on knee joint which accelerate the risk of PFPS and increase the chances of developing later acute problems such as OA (Jinks, Jordan, & Croft, 2006).

Although obesity is an important risk factor for the development of knee OA (Spector, Hart, & Doyle, 1994), recent literature reveals that not all obese persons suffer from OA nor are all individuals with knee OA obese (Sowers & Karvonen-Gutierrez, 2010). This may be explained by the BMI equation, which incorporates the entire weight of a person including their fat mass and lean mass. Lean mass is defined as muscles, bones and organs whereas fat mass includes the adipose tissue. Since the equation does not account for these distinct masses, a person can be falsely classified as obese. Hence, BMI should not solely be used to configure a therapeutic treatment plan.

It has been reported in several recent studies that obesity as a metabolic disorder is linked to low-grade chronic inflammation (Gregor & Hotamisligil, 2011; Tahergorabi & Khazaei, 2013). This is thought to be because excessive pro-inflammatory proteins called adipocytokines are found within adipose tissue in obese persons compared to non-obese persons (Greenberg & Obin, 2006). More specifically, the adipose tissue is comprised of metabolic cells called adipocytes, which secrete adipocytokines. These adipocytokines including that of leptin, adiponectin and resistin have been found in the

synovial fluid of the knee joint in OA individuals (Chen et al., 2006; Presle et al., 2006), suggesting that the adipocytokines may play an important role in joint degradation or the inflammatory processes (Sowers & Karvonen-Gutierrez, 2010). While the studies of Chen et al. (2006) and Presle et al. (2006) focus on OA, synovial inflammation has also been documented as a contributing source of patellofemoral pain (Post & Dye, 2017). Sowers & Karvonen-Gutierrez (2010) state that in order to effectively target OA with proper interventions and treatment standards, further research on adipose tissue and cardiometabolic health is required, which should also be considered when treating PFPS. These studies do not indicate that obesity causes inflammation, but suggest that the pathophysiological relationship between obesity and inflammation should not be neglected when treating knee pain. Consequently, the link between knee pain, obesity and OA requires further research, since other predictors such as genetic predisposition could be present.

Findings of genetic predisposition to OA have been discovered as early as the 1940s (Stecher, 1941) and interestingly OA heritability estimates have been reported to be 40% for the knee, 60% for the hip, 65% for the hand, and 70% for the spine (Spector & MacGregor, 2004). Although the inheritance of OA may vary by joint site (Valdes & Spector, 2010), Spector and MacGregor (2004) believe that genes are the strongest risk factor for OA within the general population.

## **2.2 Injuries**

Increased physical activity has also shown a relation to PFPS (Thomeé, Renström, Karlsson, & Grimby, 1995a) and later research by Fairbank et al. (1984) argued that



adolescent knee pain coincides with the amount of time spent playing sport. The researchers identified a correlation between anterior knee pain and frequent involvement in sport (Fairbank et al., 1984). Despite this correlation, numerous sports require cutting and pivoting such as football, lacrosse, basketball, soccer, volleyball etc. that are known to place significant stresses on the knee joint, increasing chances of injury.

In the sport of running, the same motion and technique is used repeatedly for long periods of time. “Approximately one third of serious runners will incur an injury in any given year, and approximately one third of the injuries will involve the knee” (James, 1995. p.309). In addition to training, Novacheck (1998) reported that marathon runners will take roughly 25000 steps in a race where each step applies a ground reaction force of up to several times the BW. The repetitious motion coupled with the continuous joint reaction forces in the knee joint increases the risk of developing an overuse injury. Running techniques to reduce overuse injuries include decreasing the running stride length or increasing the step rate (reduces impact load at heel strike) (Heiderscheit, Chumanov, Michalski, Wille, & Ryan, 2011) and increasing the rate of foot pronation before midstance (assures foot stability before pushoff) (Hreljac, 2004; Hreljac, Marshall, & Hume, 2000). Nonetheless, strategies to reduce overuse injuries could be offset by other factors such as running duration (Heiderscheit et al., 2011) and or recovery time. Ultimately, proper and safe training methods within any sport can essentially decrease the risk of injury.

Repetitive stresses to any joint could be harmful. More specifically, repeated and prolonged usage to the tissue triggers mechanical degradation (Shrawan Kumar, 2004), predisposing individuals to musculoskeletal injuries. This mechanism implicates the

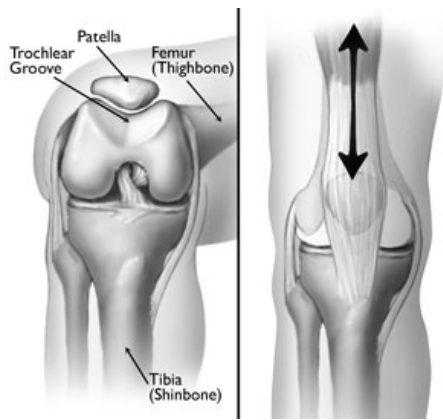
cumulative load theory which accounts for the total stress placed on the system over time (Shrawan Kumar, 2001; Magee, Zachazewski, Quillen, & Manske, 2010). Multiple studies recognized this phenomenon in low back injuries stemming from the workplace (S. Kumar, 1990; Norman et al., 1998), and in sports, particularly in golf (Bulbulian, Ball, & Seaman, 2001; Gluck, Bendo, & Spivak, 2007; Lindsay & Vandervoort, 2014; Magee et al., 2010). Golfers are exposed to the cumulative load process in the low back region because of the high frequency of swing repetitions combined with the large magnitude of spinal forces (Magee et al., 2010). Similarly, Petersen, Sorensen and Nielsen Ostergaard (2015) studied the cumulative load in the knees according to running speeds and discovered that slow-speed running had a higher cumulative load compared to fast-speed running. Their results indicated how the cumulative knee joint load per stride was diminished when running faster (Petersen, Sorensen, & Nielsen Ostergaard, 2015), suggesting that over time, slow-speed running could contribute to knee injuries. Also, individuals with knee OA showed a larger cumulative load compared to normal knees (Maly, Robbins, Stratford, Birmingham, & Callaghan, 2013), implying a probable link between the cumulative load theory, knee pain and knee OA.

Thus, the theory of cumulative loading could help explain how injuries occur. Moreover, applying the theory to particular activities can help further understand the development of knee pain in the athletic and non-athletic populations.

### **2.3 Knee Mechanics**

Patella maltracking has long been thought to play a key role in individuals with PFPS (Petersen et al., 2014). It is thus important to properly define the term patella

tracking, which differs from patella alignment. The patella and the trochlear groove of the femur are the main anatomical structures associated to patella alignment and patellar tracking. Further, the dynamic relationship between the two during knee motion defines the latter, whereas the static relationship between the patella and the trochlear groove during any degree of knee flexion describes patella alignment (Saifuddin, 2008) (Figure 1).



**Figure 1:** Left image displaying the patella as it normally rests in the trochlear groove (patella alignment). Right image representing the patellar glide within the groove as the knee flexes and extends (patella tracking) (Hettrich & Liechti, 2015).

To explain proper tracking, the patella glides vertically in the trochlear groove causing the femoral condyles to slide behind the patella (Frisch, 2012); when the knee joint extends, the patella glides back through the trochlear groove and completes its tracking once it reaches the border of the femoral condyles (Frisch, 2012; Long et al., 2015). More precisely, Neumann (2013) describes proper tracking as the patellar movement across the trochlear groove of the femur with the “greatest possible area of articular surface with the least possible stress” (p.546). This total range is approximately 6cm (Frisch, 2012) and as described by Bártolo & Bidanda (2007), the symmetric position of the patella during the

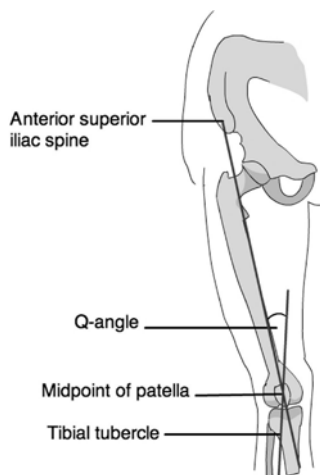
motion is imperative to a healthy functional knee.

Soft tissue stabilizers control the patellar movement through the trochlear groove, which signifies patellar tracking (Dixit, Difiori, Burton, & Mines, 2007). Imbalances between these tissues causes patellar maltracking (Dixit et al., 2007; Pedowitz, Chung, & Resnick, 2008). Definite bony dysplasia and abnormalities that could predispose to PFPS and result in excessive maltracking of the patella include: Patella alta (patella situated high) and patella infera (shallow patella) (Neumann, 2013); genu varum (bowleg) and genu valgum (knock-knee) (W. Petersen et al., 2014). Therefore, clinical assessment and evaluation of potential conditions and pathologies remain important as they could influence therapeutic treatment.

Normal knee mechanics differ between men and women. These differences appear in lower extremity alignment, specifically with the quadriceps femoris angle (Q-angle), muscle strength and muscle flexibility (Malinzak, Colby, Kirkendall, Yu, & Garrett, 2001).

### **2.3.1 Q-angle**

An important yet controversial determinant of patellar tracking is the Q-angle. The Q-angle is the angle in which the femur encounters the tibia (Figure 2). Specifically, it is the line connecting the anterior superior iliac spine to the center of the patella and the line connecting the middle of the anterior tibial tuberosity to the center of the patella (Aglietti, Insall, & Cerulli, 1983; Biedert & Warnke, 2001; Heiderscheit, Hamill, & Van Emmerik, 1999; L. Livingston, 1998).



**Figure 2:** Q-angle (Marra, 2013).

This measurement varies significantly as it can be taken in various positions, such as supine or standing. The supine Q-angle measurement could either be taken with the knees extended and legs relaxed (Aglietti et al., 1983) or knees extended, legs relaxed but keeping the hip in a neutral position with parallel feet (Guerra, Arnold, & Gajdosik, 1994). The standing Q-angle measurement could be taken either with the feet placed together (touching medially) (L. A. Livingston & Spaulding, 2002), or with a separation of 7.5cm of the heels and a 10° external forefoot rotation from the medium line, keeping the quadriceps relaxed (Woodland & Francis, 1992). In terms of instruments used to measure the angle, some studies utilized computerized biophotogrammetry (photographs capable of producing measurements) with markers placed on the anatomical landmarks (Hahn & Foldspang, 1997; L. Livingston & Mandigo, 1999; Woodland & Francis, 1992), while others measured the angle with a goniometer (Guerra et al., 1994; LA Livingston & Mandigo, 1999; Nguyen & Shultz, 2007; Shultz et al., 2006). Thus, the various Q-angle measuring techniques increases its sensitivity to error (Fredericson & Yoon, 2006).

Controversy exists between male and female Q-angles and whether or not there is

a difference. Early research by Caylor et al. (1993) implies that no universal normal Q-angle value exists, while more recent research reveals normal Q-angle values of 13° and 18° respectively for men and women (Magee, 2014). Furthermore, Grelsamer, Dubey and Weinstein (2005) indicate that the Q-angle in women is known to be greater than those of men due to the fact that women have wider pelvises. Interestingly, a study using a sample population of children found no significant differences between the Q-angles of boys and girls between 7-12 years of age (Bhalara, Talsaniya, Nikita, & Gandhi, 2013). However, while studying this measurement in an adult population previous research found differences between the Q-angles of men and women ranging from 3° to 4.6° (Horton & Hall, 1989; Hsu, Hilmeno, Coventry, & Chao, 1990; LA Livingston & Mandigo, 1999; Woodland & Francis, 1992). However, a study conducted in 2005 found a mean difference of only 2.3° between gender Q-angles (Grelsamer et al., 2005). A surprising finding in this study was that “men and women of equal height demonstrated similar Q-angles, with taller people having slightly smaller Q-angles” (Grelsamer et al., 2005, p.1498). They explained that the gender difference was eliminated when height was accounted for (Grelsamer et al., 2005). Therefore, this could help justify the minor Q-angle differences found between sexes given that men are on average taller than women. Nonetheless, differences in the Q-angles according to gender remain unclear and furthermore, values considered to be within normal range have yet to be established.

The relationship between PFPS and Q-angles are generally acknowledged. As such, greater Q-angles have been shown to cause a lateral pull on the patella (Emami, Ghahramani, Abdinejad, & Namazi, 2007), given that the measure from the anterior superior iliac spine to the center of the patella (lateral component of the resultant force) is

higher, therefore increasing the lateral contact forces (Mizuno et al., 2001; Tumia & Maffulli, 2002). Having said this, greater contact forces within the PFJ have been implicated as a source of patellofemoral pain (M. Baker & Juhn, 2000; Massada, Aido, Magalhães, & Puga, 2011; Thomeé et al., 1999). Consequently, high Q-angles may be associated to PFPS. However, Q-angles for symptomatic and asymptomatic PFPS populations are similarly controversial. Previous studies have reported no Q-angle correlation between PFPS and a healthy population (Caylor, Fites, & Worrell, 1993; Fairbank et al., 1984; Thomeé, Renström, Karlsson, & Grimby, 1995b), while differences of a few degrees were observed in a more recent study (Näslund, Näslund, Odenbring, & Lundeberg, 2006). The variable Q-angle measuring techniques could help explain the research incongruities surrounding this matter.

### **2.3.2 Muscle Strength**

The amount of muscle force affects the amount of pressure produced across the joint. Muscle strength could be defined in two ways: absolute and relative. Absolute strength, the term most commonly used when describing strength is the amount of force that can be exerted. Relative strength on the other hand, takes into account one's body mass, fat-free body mass or muscle cross-sectional area (McArdle, Katch, & Katch, 2007; Swedan, 2001). Previous research reveals that the average woman exhibits approximately two thirds of the total absolute force of an average man (Holloway & Baechle, 1990). Particularly, women score approximately 50% lower than men for upper-body strength, and approximately 30% lower for leg strength when comparing absolute muscle strength (McArdle et al., 2007). Furthermore, during adulthood the muscle mass for non-obese

females and males is 25-35% and 40%-45% respectively of their body weight (Åstrand, 2003). Fundamentally, muscle mass and hormone variations help explain the absolute strength differences between men and women (V. M. Miller & Hay, 2004).

In terms of relative strength, differences between men and women are reduced (Gregory & Travis, 2015). This could be explained by the fact that the strength per unit of a muscle's cross-sectional area (i.e. biceps) is equivalent for men and women (V. M. Miller & Hay, 2004). The muscle cross-sectional area is calculated by the muscle fibre size multiplied by the number of muscle fibers (A. E. Miller, MacDougall, Tarnopolsky, & Sale, 1993; Swedan, 2001). Although the number of muscle fibers between sexes is controversial (Holloway & Baechle, 1990; A. E. Miller et al., 1993), an earlier study reveals that this number could be established at birth (Van DeGraaff, 1984). Nonetheless, strengthening programs for both men and women should be comparable due to the similar relative strength gains between sexes (Kell, 2011).

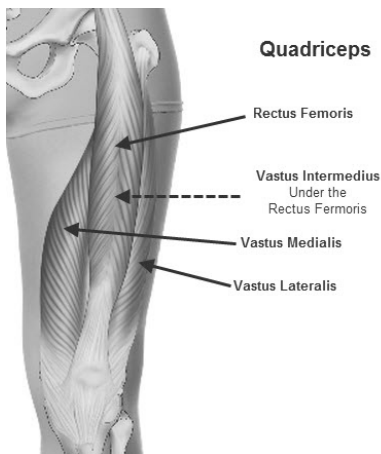
Another important determinant of muscle strength is genetics (Cardinale, Newton, & Nosaka, 2011). There is a correlation between muscle strength and bone mineral density (BMD) where BMD is found to be under genetic control (Arden & Spector, 1997). Because individuals inherit different genes, physical traits including muscle strength are influenced. Furthermore, prior research indicates that genes account for approximately half, if not more of the difference in human muscle strength (Carmelli & Reed, 2000; Frederiksen et al., 2002; Reed, Fabsitz, Selby, & Carmelli, 1991).

Muscle strength differences specifically regarding muscle imbalances have been shown as a contributing factor to PFPS. In fact, some studies concluded that females with PFPS in one knee have shown hip muscle strength deficiency in abduction when



compared to their unaffected knee (Cichanowski, Schmitt, Johnson, & Niemuth, 2007; Magalhães et al., 2010; Van Cant, Pineux, Pitance, & Feipel, 2014), or compared to aged matched controls (Ireland, Willson, Ballantyne, & Davis, 2003). This atrophy can cause the femur bone to rotate internally, causing lateral patellar tracking, resulting in greater lateral forces acting on the knee joint (Huberti & Hayes, 1984; Lee, Yang, Sandusky, & McMahon, 2001; Mizuno et al., 2001; T. Smith, Bowyer, et al., 2009). Interestingly, a recent longitudinal study over a 5-year period concluded that women's quadriceps weakness posed an increased risk to knee pain whereas with men it did not (Glass et al., 2013). It is important to note that the participants involved in the study were individuals with knee OA or individuals with known risk factors for knee OA. Since the quadriceps muscles are inserted on the patella, quadriceps weakness has also been an important aspect to consider when treating knee pain.

The vastus medialis oblique (VMO) muscle is considered to be the main active medial stabilizer of the patella (Halabchi, Mazaheri, & Seif-Barghi, 2013). This muscle has long been thought to help guide the patella during movement (Bose, Kanagasuntheram, & Osman, 1980), and is found to be weakened in individuals with PFPS (Halabchi et al., 2013). Weakness in this muscle can result in lateral patellar maltracking given the fact that the patella is exposed to greater lateral forces from the vastus lateralis (VL) muscle (Figure 3) (Halabchi et al., 2013).



**Figure 3:** Quadriceps muscles including the Vastus medialis muscle (VMO) and the Vastus lateralis muscle (VL) (Richards, 2016).

In theory, in order to correct this imbalance, exercises targeting the VMO should increase the VMO/VL strength ratio. Researchers Willis, Burkhardt, Walker, Johnson and Spears (2005) discovered that when cycling at 85 rpm the VMO muscle activation was favoured compared to the VL muscle through surface electromyography. Additionally, prior research has identified VMO activation achievement in closed kinetic chain exercises at 60° of flexion (Tang et al., 2001) and greater VMO/VL ratios were recently reported in a healthy male population when performing the squat exercise (Yoo, 2015). Although, simply targeting the VMO muscle has been debatable (T. Smith, Bowyer, et al., 2009), exercises designed to strengthen this muscle are important within a symptomatic population given its general objective to guide the patella properly during movement (Bose et al., 1980; Halabchi et al., 2013).

### **2.3.3 Muscle Tightness**

In terms of flexibility, research shows that women tend to be more flexible than men (Alter, 2004; Payne, Gledhill, Kazmarzyk, Jamnik, & Keir, 2000; Swedan, 2001).

Women's pelvic structure and hormones affecting connective tissue laxity could explain such differences (Alter, 2004). Nevertheless, muscle stiffness within both genders can result in patellar mal-tracking (Vicente Sanchis-Alfonso, 2011), leading to PFP.

Tight hamstring muscles have been theorized to elicit greater quadriceps forces in order to overcome the passive resistance from the hamstrings, causing increased PFJ reaction forces (Piva, Goodnite, & Childs, 2005). Wang, Whitney, Burdett and Janosky (1993) indicate that male runners have increased tightness in the hamstring muscles when compared to females. Yet, more recent research concludes that female and male athletes have different knee motion patterns in athletic tasks such as running, side cutting and cross cutting, where females contraction was greater for quadriceps muscle activation and lower for hamstring muscle activation as a percentage of maximum voluntary contraction (Malinzak et al., 2001). Still, the correlation between poor hamstring flexibility in both genders and PFPS has been proven (Piva et al., 2005; A. Smith, Stroud, & McQueen, 1991).

Piva et al. (2005) studied flexibility of soft tissue between patients with PFPS to gender-matched control subjects without PFPS and found that the control group was more flexible in the hamstrings, quadriceps, gastrocnemius and soleus muscles, concluding that individuals with PFPS have tighter leg musculature (Piva et al., 2005). Another muscle that has been theorized to have an influence on PFPS and patella tracking is the iliotibial band (ITB) (Hudson & Darthuy, 2009). This muscle is inserted into the patella into its attachment of the lateral retinaculum, and was tighter in individuals with PFPS compared to healthy individuals (Hudson & Darthuy, 2009).

The negative association of tight musculature in the lower limbs are well

documented: limiting the range of motion and creating muscle imbalances (Page, 2012), in which the latter can lead to patellar maltracking (Dixit et al., 2007; Pedowitz et al., 2008). The inclusion of flexibility exercises in PFPS treatment programs is therefore essential since this population is known to have greater lower limb tightness (Hudson & Darthuy, 2009; Piva et al., 2005). Moreover, a later study investigated adolescent athletes with anterior knee pain, and found that knee pain was completely eliminated by incorporating flexibility exercises specific to the thigh region (Smith et al., 1991). Therefore, stretching exercises specifically targeting the quadriceps, hamstrings, ITBs and gastrocnemius should continue to be included in PFPS treatment programs.

## **2.4 PFPS Left Untreated**

Ongoing knee pain should not be ignored to reduce the risk of permanent knee damage. OA is found to be most common in the knee (Valderrabano & Steiger, 2010). This irreversible condition is defined as a degenerative joint condition (Valderrabano & Steiger, 2010) in which wear and loss of articular cartilage within the synovial joint results in bone on bone friction, causing inflammation and pain (Jerosch, 2011).

The development of OA is gradual and can occur to any joint, however weight-bearing joints such as the knee and hip are most susceptible (Jerosch, 2011). Some main risk factors of OA include age (Aigner, Haag, Martin, & Buckwalter, 2007; Shane Anderson & Loeser, 2010), being overweight, obesity (Blagojevic, Jinks, Jeffery, & Jordan, 2010) and genetic determinants (Spector & MacGregor, 2004). Previous research identified a large portion of patients with knee OA having anterior knee pain earlier in life (Utting, Davies, & Newman, 2005). They raise the question as to whether knee pain

predisposes individuals to knee OA later in life (Utting et al., 2005). Above all, knee pain treatment remains imperative as it can lead to a physical disability as well as a decreased quality of life (Ayis & Dieppe, 2009; Kim et al., 2011).

Based on current literature, OA is a leading cause of knee pain in older populations (Kim et al., 2011; Laba, Brien, Fransen, & Jan, 2013), affecting individuals over the age of 55 (Jinks, Lewis, Ong, & Croft, 2001). Due to our aging population, Woolf and Pfleger (2003) predict that by 2020 OA will globally become the fourth leading cause of disability. Although OA is present in both genders, the severity of the knee arthritis is greater in women (O'Connor, 2007). Kim and colleagues (2011) discovered that as women age the prevalence of knee pain increases, whereas with men it does not. They hypothesize that, in women, aging factors i.e. muscle weakness compared to men could be the reason of such findings (Kim et al., 2011). However, since there is no known cure for OA, its irreversibility affects both genders (Woolf & Pfleger, 2003). Ultimately, the pain associated with OA could lead to reduced functional independence and decreased quality of life (de Rezende, de Campos, & Pailo, 2013; Dominick, Ahern, Gold, & Heller, 2004; Mili, Helmick, & Moriarty, 2003). Therefore, when knee pain is recognised it is imperative to commence conservative therapy immediately to prevent the possibility of physical disability later on.

## **2.5 Treatment Methods**

The complexity of PFPS creates a challenging and difficult syndrome for clinicians and physiotherapists to treat. Remarkably, several treatment methods for this syndrome show encouraging results. Conservative management including: exercises,

patella taping and bracing, are some of the recommended choices for treating patellofemoral conditions (Peters & Tyson, 2013). Surgical treatment has also been performed (Goldberg, 1997), but only recommended once conservative management fails (McCarthy & Strickland, 2013). Arthroscopy, a surgery to repair or remove damaged tissue from the joint, is the most commonly performed surgery for PFPS reported in the literature. During this surgery the surgeon may prefer to complete the entire arthroscopic examination of the knee before proceeding with arthroscopy procedures or may prefer to address the pathologic conditions as they are encountered (Gill, 2009). The latter is generally preferred to reduce making unnecessary passes through the knee (Gill, 2009). Some arthroscopic procedures for PFPS consisted of the lateral retinacular release (cutting the lateral retinaculum) (Fulkerson, 1994; Fulkerson, Schutzer, Ramsby, & Bernstein, 1987; Pidorian & Fulkerson, 1997), shaving the damaged cartilage and removing the fragments to leave a smooth surface (Kettunen et al., 2007; Ogilvie-Harris & Jackson, 1984) and or resection or partial resection (removing damaged tissue) (Kettunen et al., 2007). Whether or not the surgical procedure will produce more pain is an important question the surgeon should consider (Fulkerson, 2002). Kettunen et al (2007) explained that since most physicians prefer conservative therapeutic treatment, arthroscopy is generally utilized once therapy has been exhausted. However, the same researchers conducted a randomized control trial comparing arthroscopy combined with an exercise program to an exercise program and found no significant difference. This discovery lead them to eliminate arthroscopy as a PFPS treatment choice (Kettunen et al., 2007). Exercise programs designed to correct muscle tightness (stretching the quadriceps, hamstrings, gastrocnemius and iliotibial band) and muscular imbalances (strengthening

the VMO muscle) are recommended in the exercise prescription for PFPS (Harvie et al., 2011).

Exercise therapy has consistently been found, in multiple studies, to be effective in reducing pain in patients with PFPS (Bolgla & Boling, 2011; Gielen & Sleet, 2003; Harvie et al., 2011; Heintjes et al., 2003). In fact, researchers state that 2/3 of PFPS patients are successfully treated through physical therapy programs (Dehaven, Dolan, & Mayer, 1979; Kannus, Natri, Paakkala, & Järvinen, 1999; Whitelaw, Rullo, Markowitz, Marandola, & DeWaele, 1989). More specifically, both open kinetic chain and closed kinetic chain exercises have been shown to benefit this population (Bolgla & Malone, 2010; Fagan & Delahunt, 2008), yet closed kinetic chain exercises are preferred because they limit stress and forces across the PFJ (Wyss & Patel, 2012). An open kinetic chain exercise is when the lower extremity end is not fixed to an object and is free to move (i.e. knee extension when sitting), whereas a closed kinetic chain exercise is when the distal end of the lower extremity is fixed to an object that is either stationary (i.e. squat) or moving (i.e. leg press) (Ellenbecker & Davies, 2001). During the latter, the PFJ reaction force (measure of compression of the patella against the femur) and patellofemoral contact area increases with knee flexion (McGinty et al., 2000), resulting in a decrease in patellofemoral contact stress. On the other hand, patellofemoral contact stress increases during knee extension (until the patella is no longer in contact with the trochlea (20°)), due to greater PFJ reaction forces and decreases in the patellofemoral contact area (McGinty et al., 2000). Having said this, a reduction in PFP across the PFJ for closed kinetic chain exercises lies within 0°-45° of knee flexion (McGinty et al., 2000). While the full squat exercise consists of both occurrences (decreases in contact stress during

flexion and increases in contact stress during extension), limiting the knee flexion angle to 45° should be considered for individuals with PFPS. Particular open kinetic chain exercises such as straight leg raises can also benefit this symptomatic population (McGinty et al., 2000), given that the leg is in extension ( $\approx 0^\circ$ ), limiting the PFJ reaction forces. Thus, both closed and open kinetic chain exercises can be prescribed to a symptomatic population. Harvie et al. (2011) studied several exercise programs developed specifically for PFPS and found positive results with: knee extensions, squats, active leg raises, leg press, step-up and down exercises and stationary cycling. Further, these exercises focus on improving quadriceps strength, specifically enhancing the VMO muscle function (Wyss & Patel, 2012), limiting the stress on the patella (McGinty et al., 2000).

The recommended duration and frequency of treatment programs differs in the literature. In terms of strengthening exercises, Crossley et al (2002) studied the effects on patellofemoral pain throughout a six-week period where the participants in this study received treatment from a physiotherapist once a week yet had to perform the exercises daily. The participants performed a total of three exercises during the first two weeks (contracting the VMO while sitting, squats and isometric abduction against a wall in standing) with an addition of two exercises for the remaining four weeks (step down exercises and isometric hip abduction in standing) (Crossley et al., 2002). The frequency of the exercises varied from 3-4 sets of 10 repetitions each, and their results indicated that this standardised course of therapy was effective for reducing patellofemoral pain (Crossley et al., 2002). On the other hand, Witvrouw, Lysens, Bellemans, Peers and Vanderstraeten (2000) have found positive results with similar exercises prescribed three



times per week for five weeks consisting of 3 repetitions of 10 sets. Exercises prescribed two to three times a week during a three to four week period has also been suggested for PFPS (Bolgla & Malone, 2005; Wyss & Patel, 2012).

Exercises addressing flexibility in the lower limb musculature such as: hamstrings, quadriceps, plantarflexors and ITB stretches were also commonly used and supported for PFPS treatment (Harvie et al., 2011; Wyss & Patel, 2012). A common PFP stretching parameters in the literature consists of three repetitions of 30 seconds, two-three times a week (Herrington, 2002; Song et al., 2009; Witvrouw et al., 2000).

Indeed, research by Harvie et al. (2011) stipulates that exercise therapy in conjunction with other treatment options such as external patellar support (knee bracing and patellar taping), education etc. can further the success of treating individuals with PFPS. Correspondingly, pain relief has been identified when incorporating external patellar supports (Powers, 1998). Despite these results, there is controversy between the overall effects of these supports after treatment.

A popular patellar support consists of the McConnell medial taping technique (Campolo et al., 2013; W. Petersen et al., 2014), in which several researchers support the use of this method in addition to PFPS rehabilitation (Cowan, Bennell, & Hodges, 2002; Rathleff, Roos, Olesen, & Rasmussen, 2012). Jenny McConnell, a renowned physiotherapist introduced this added technique in the mid 1980's to restore normal patellar tracking (McConnell, 1986). This taping method is believed to correct patellar mal-alignment and enhance VMO muscle activity, all in which progresses treatment as it targets two essential factors in the management of PFPS (McConnell, 1986). This technique is a simple modality that could be applied by the individuals themselves

(McCarthy & Strickland, 2013), which was the case in some studies, where participants with PFPS were taught how to apply the tape independently and were instructed to wear the tape daily (Cowan et al., 2002; Rathleff et al., 2012).

McConnell's taping technique has been shown to be effective in decreasing pain (Bockrath, Wooden, Worrell, Ingersoll, & Farr, 1993; Christou, 2004; Cowan et al., 2002; D'hondt et al., 2002; Kowall, Kolk, Nuber, Cassisi, & Stern, 1996; Ng & Cheng, 2002; Powers et al., 1997; Warden et al., 2008), however the effects on patellar alignment remain questionable. Larsen, Andreasen, Urfer, Mickelson and Newhouse (1995) studied McConnell's taping technique in a healthy population and found through radiographic imaging that the patella returned to the original misalignment position after treatment. It is important to note that their treatment protocol consisted of taping one knee and having each participant undertake the same exercise program during approximately 10 to 15 minutes, which included five sets of three repetitions with one-minute rest period between each set (Larsen et al., 1995). It is reasonable to assume that 10 to 15 minutes of exercise may be insufficient to observe physical or mechanical changes, which may help explain why no differences were detected. Despite this observation, the duration of treatment required to mechanically realign the patella has not yet been determined. Furthermore as stated by Pfeiffer et al. (2004), the study by Larsen et al., (1995) imaged the knee at a 40° angle presenting a possible limitation, given the fact that the patella is engaged in the trochlear groove and less prone to subluxation. Pfeiffer et al. (2004) conducted a similar study to that of Larsen et al. (1995) with a purpose to detect alignment effects with the McConnell taping technique using a kinematic Magnetic Resonance Imaging (MRI) procedure. With the same exercise program prescribed,

Pfeiffer et al. (2004) used MRI images of four knee flexion angles: 0°, 12°, 24° and 36° and found that the medial patellar position post exercise was not maintained. Nonetheless, subjects without knee pain participated in their study, presenting a limitation to detect change in a healthy knee.

Gigante, Pasquinelli, Paladini, Ulisse and Greco (2001) compared the taping effect within a symptomatic population and found no difference in patellar positioning with Computed Tomography (CT). While the McConnell taping method was used, the participants in this study were simply required to perform a maximal isometric voluntary contraction at 0° and 15° with and without tape (Gigante et al., 2001) therefore, the patellar alignment effects following one exercise may not properly represent the effects following a regular exercise program.

The effect of patellar taping incorporated with other therapies on the patella alignment still requires attention. Based on this review of the literature, a study focusing on the prevalent McConnell medial taping technique in combination with therapeutic exercise as prescribed in a clinical setting would contribute new knowledge to PFPS research.

## **2.6 Purpose**

Although PFPS is known to be a complex syndrome, current research indicates that 50% of individuals with PFPS have patellar malalignment (Karimzadehfini, Zolaktaf, & Vahdatpour, 2014). Because patellar malalignment is still widely regarded as a clinical sign of PFPS and instability (T. Smith, Davies, & Donell, 2009), therapeutic treatment methods are imperative and remain at the forefront of this diagnosis. The McConnell

medial taping technique is extensively implemented in clinical settings as it is believed to assist in re-aligning the patella via medial directed force, which in turn allows the patella to track properly (W. Petersen et al., 2014). While a knee brace may have similar effects, the current study seeks to particularly test the McConnell taping technique's theory in realigning the patella. This taping method will allow the participants to apply the tape independently, and wear it comfortably underneath clothing throughout the day with a lesser chance of developing irritation.

The specific aim of this study is to address the effects of patellar taping on alignment in conjunction with exercise therapy in individuals diagnosed with PFPS.

## **2.7 Research Questions**

The questions used to guide this research were the following:

1. Will a therapeutic exercise program with and without knee taping designed to treat PFPS lead to a change in patellar alignment in men and women between 20-50 years of age?
2. Will the implementation of a therapeutic exercise program with and without taping for PFPS lead to improved perceived pain intensity during ADL in men and women between 20-50 years of age?

## **2.8 Hypotheses**

### **2.8.1 Patella Measurement Hypothesis**

Hypothesis 1 – Knee taping for PFPS in conjunction with a therapeutic exercise program will improve the patellar alignment to a greater extent than the therapeutic exercise

program on its own.

### 2.8.2 Perceived Pain Hypothesis

Hypothesis 2 – Knee taping for PFPS in conjunction with a therapeutic exercise program will reduce the perceived pain intensity to a greater extent than the therapeutic exercise program on its own when ascending stairs.

Hypothesis 3 – Knee taping for PFPS in conjunction with a therapeutic exercise program will reduce the perceived pain intensity to a greater extent than the therapeutic exercise program on its own when descending stairs.

Hypothesis 4 - Knee taping for PFPS in conjunction with a therapeutic exercise program will reduce the perceived pain intensity to a greater extent than the therapeutic exercise program on its own when standing from a seated position.

Hypothesis 5 - Knee taping for PFPS in conjunction with a therapeutic exercise program will reduce the perceived pain intensity to a greater extent than the therapeutic exercise program on its own for worst pain ever felt within the last six weeks.

**CHAPTER III**  
**METHODOLOGY**

### **3.0 Study Design**

The study design consisted of a non-random quasi-experiment clinical trial in which the participants assessed with PFPS selected their preferred group (exercise with tape or non-tape). Both groups consisted of symptomatic PFPS populations.

#### **3.1 Sample Size Calculation**

Sample size was determined based on utilizing the VAS as an outcome pain measure and the established standard deviation of 2 cm from previous studies. In order to obtain a power of 85% and  $p=0.05$ , the number of participants for each group (taped and non-taped) would be 33.

#### **3.2 Recruitment Strategy and Changes**

Originally the recruitment would have occurred in pre-approved physiotherapy clinics accessing a fairly large population of PFPS. However, a temporary change in management staffing of these clinics, revoking permission, resulted in a last minute change to the recruitment procedures. Posters were set-up at the University and in the University Athletic Therapy Clinic where the participants were recruited via sample of convenience through advertisement of these locations (Appendix A).

#### **3.3 Statistical and Non-Statistical Design**

The research study was first analyzed using the non-parametric Wilcoxon Sign Rank Test, and second by plotting individual scores on a case-by-case basis given the limited sample size. The Wilcoxon test contains two time intervals: before starting

session 1 and 24 hours following session 12 for each treatment group. Group 1 consisted of taping and exercise and group 2 consisted of no taping and exercise. Additional Wilcoxon Sign Rank Tests were utilized for the four pain measurement scores; ascending stairs, descending stairs, standing from a seated position and worst pain ever felt within the last six weeks. These tests included same two time intervals: before starting session 1 and 24 hours following session 12, for each treatment group: taping with exercise and non-taping with exercise.

### **3.4 Inclusion and Exclusion Criteria**

Individuals having had anterior knee pain for more than 12 months aggravated by sitting, squatting and or stair walking were invited to participate in the study. Both men and women were included however, in order to avoid early symptoms of osteoarthritis; individuals had to be between the ages of 20-50 years old. Participants who had knee surgery and or lower limb/joint replacement within the last year were excluded. Participants diagnosed with rare occurring conditions and pathologies such as peripatellar bursitis or tendinitis and plica syndrome were also excluded (Crossley et al., 2002; Gigante et al., 2001; Heintjes et al., 2003; Watson, Propps, Galt, Redding, & Dobbs, 1999), along with individuals with severe or moderate arthritis in the knee and or those having received cortisol/steroid injections to the knee within the last six months (Crossley et al., 2002). Finally, individuals taking any anti-inflammatory medication were excluded and individuals with past allergic reactions to tape were excluded from the taping group.

The Clarke's Sign Test (Patellar Grind Test) as well as the Step Up Test were used to corroborate the self-reported diagnosis of PFPS (Magee, 2002, 2014), which was



conducted by the physiotherapist. The Clarke Sign Test is commonly used to assess PFPS (Bronstein & Schaffer, 2017; Kwon, Yun, & Lee, 2014). This test involved pressing down at the base of the patella while in a supine position using the web of the hand and asking the patient to contract their quadriceps muscles for a few seconds. If the patient experienced no pain throughout the contraction it is considered negative whereas if the patient cannot hold the contraction and experienced retropatellar pain, the results was positive. The physiotherapist carefully monitored the amount of pressure applied, since a positive test could be found with anyone given enough pressure (Magee, 2002). The specificity, being the true negative rate of this test showed a positive likelihood ratio of 1.94 (Nijs, Van Geel, Van der auwera, & Van de Velde, 2006). This value represents fair specificity, meaning that positive results from the Clarke Sign Test are generally true for an individual with PFPS. However, the sensitivity, which is the true positive rate of this test denoted low sensitivity (0.39) (Doberstein, Romeyn, & Reineke, 2008), meaning that negative test results from the Clarke Sign Test does not guaranty that the individual does not have PFPS. Thus, the Step Up Test was also utilized to test for PFPS.

The Step Up Test consisted of having the patient step up sideways onto a stool of 25cm (10 inches) using one leg and then repeated with the opposite leg (Muller & Snyder-Mackler, 2000). The test was considered positive if the patient experienced pain (Nijs et al., 2006). Furthermore, difficulty performing the test indicated instability which can be a sign of PFPS involving weak quadriceps muscles (Magee, 2002, 2014). The Step Up Test has revealed good intra-rater reliability (0.94) (J. Loudon, Wiesner, Goist-Foley, Asjes, & Loudon, 2002) and good specificity (positive likelihood ratio of 2.34) (Nijs et al., 2006).

Following the physiotherapist's assessment (Clarke Sign and Step Up Test), the researcher provided information on the study and the participant signed the informed consent form if they wished to participate.

### 3.5 Participant Demographics

Eight participants, with PFPS, between 20-50 years of age completed the four-week intervention (taped,  $n=4$  and non-taped,  $n=4$ ).

Of the eight participants, three were female and five were male: two female and two male participants chose the taping group and one female and three male participants chose the non-taping group.

The demographic features were calculated for each group (Table 1). There were no statistical significant differences between the two groups (age  $p=0.180$ , height  $p=1.000$ , weight  $p=0.920$ , BMI  $p=0.840$ ).

**Table 1:** Demographic features of both the Taped ( $n=4$ ) and Non-Taped ( $n=4$ ) group

	age (years)	height (cm)	weight (kg)	BMI (kg/m <sup>2</sup> )
Taped	40.3 $\pm$ 8.4	174.8 $\pm$ 22.3	85.9 $\pm$ 22.8	28.6 $\pm$ 8.8
Non-Taped	29.0 $\pm$ 12	174.8 $\pm$ 3.9	84.2 $\pm$ 28.1	27.4 $\pm$ 8.3

$\pm$  standard deviation

### 3.6 Data Collection

The data were collected during a four-week period between February 22<sup>nd</sup> and March 31<sup>st</sup> 2016.

Informed consent was mandatory for all participants willing to participate in the study (Appendix B). If the participant wished to take more time to read the informed consent, make a decision at a later time, or had any questions regarding the research, they

were granted the time they needed and called or emailed the researcher about any questions or concerns.

Following participants' consent to participate in the study, they were identified with a number to ensure anonymity and confidentiality, which was recorded on a printed hard-copy data collection sheet (Appendix C). On the data collection sheet, participants were asked to record their anthropometric information including: age, height and weight. The BMI were calculated based on this information because BMI is a known risk factor associated to PFPS (Betancourt & Hannafin, 2007). For the duration of the study, the physiotherapist identified each participant with his or her corresponding number and the researcher would then record the patellar measurements provided by the physiotherapist. Following the measurements, participants were asked to mark their perceived pain levels on the VAS. All information was recorded on the data collection sheet, which was then collected by the researcher.

### **3.7 Procedure**

Due to ethics concerns expressed by the university committee that not all participants would receive the standard of care for treatment, participants were not randomly assigned to groups. Instead the participants were asked to select a preferred group: taping and regular treatment or no taping and regular treatment. The physiotherapist continued the PFPS exercise treatment plan with the incorporation of tape or no tape depending on the participants' group preference. Additionally, the participants were numbered to ensure patient-confidentiality, and the physiotherapist provided the researcher with the participant's number prior to each individual data collection.

For the participants in the taping group, the physiotherapist demonstrated the McConnell taping technique, provided pre-cut Leukotape (high strength rigid tape) strips and delivered instructions to wear the tape for the duration of the treatment (removing the tape at night and reapplying it in the morning). The taping technique as described by Callaghan, Selfe, Bagley and Oldham (2002) involves applying tape to the knee in a seated position with the leg extended and relaxed. The center of the strip placed as near as possible to the center of the patella fixing the lateral edge of tape in alignment with the lateral joint line (Callaghan et al., 2002). Slight tension is then placed on the tape towards the medial side of the knee (promoting proper patellar alignment in individuals with PFPS), where the medial side of tape fixed to the skin (Callaghan et al., 2002). The physiotherapist measured the taping length required for each participant on a case-by-case basis to ensure that the tape covered the landmarks and provided the individuals with the pre-cut strips. Each participant was given a chance to practice the taping method while in the presence of the physiotherapist in order to feel comfortable and to ensure proper application.

With regards to the treatment plan, both groups were prescribed the same exercise program including strengthening exercises and flexibility exercises (Appendix D). The exercises were prescribed three times a week for four weeks and were repeated ten times for a total of three sets. The four-week exercise duration has been used in other studies investigating PFPS, showing effective results (Bolgla & Malone, 2005; Fukuda et al., 2010, 2012; Razeghi, Etemadi, Taghizadeh, & Ghaem, 2009; Wyss & Patel, 2012). The flexibility exercises were performed three times with a thirty-second hold. Under the supervision of the physiotherapist during the initial visit, the participants executed the

first exercise session to ensure proper technique of the exercises. For the remainder of the treatment, participants conducted the exercise sessions at home unsupervised.

### **3.8 Variables**

The dependent variables considered in the study include the patellar displacement and four pain measurements (ascending stairs, descending stairs, standing from a seated position and worst pain ever felt within the last six weeks). The independent variables considered in the study are the two treatment groups (group 1 taping and group 2 non-taping) and two time intervals (before starting session 1 and 24 hours following session 12).

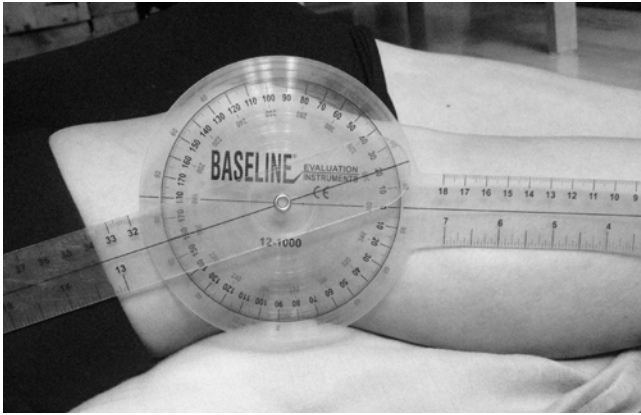
The rationale for including the time interval as a variable is that it allows the researcher to evaluate progress over time. The four pain measurements in the study stemmed from previous research and current outcome measures taken in physiotherapy clinics. In particular, ascending stairs, descending stairs, and standing from a seated position are outcome measures that are found to be prevalent to help with PFPS diagnoses. Further, the worst pain ever felt within the last six weeks was incorporated as a variable as it is a common question asked in clinical settings and used to observe the overall effect of the treatment on the individual's ADL.

### **3.9 Instruments**

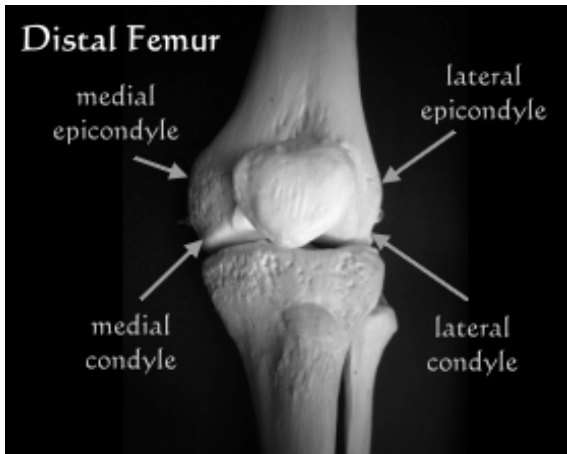
The first component of the study consisted of measuring the patellar displacement using the technique described by McConnell (1996) and further portrayed by Herrington (2002). Although prior research indicates poor/fair reliability of this method (Fitzgerald

& McClure, 1995; Tomsich, Nitz, Threlkeld, & Shapiro, 1996; Watson et al., 1999) with  $k$  coefficients for intratester and intertester reliability ranging from -0.06 to 0.35 and -0.03 to 0.19 respectively (Watson et al., 1999), more recent research support this method as a reliable measure:  $r = 0.91$  medial measurement and  $r = 0.94$  lateral measurement if conducted by an experienced manual physiotherapist (Herrington, 2002). In the current study, consistency was maintained as a result of having the same physiotherapist perform the assessments, instruct participants on the taping mechanism and measure the patellar distances. The physiotherapist willing to participate in the study had been working as a registered physiotherapist for 7 years with 12 years of clinical experience. There was no personal relationship between the researcher and physiotherapist.

The patellar displacement is measured in a seated position with both legs extended, the quadriceps relaxed and the symptomatic leg is positioned and supported in a  $20^\circ$  angle. This angle, measured with a goniometer has been previously reported as the angle in which the femur enters the trochlear groove (Thomeé et al., 1999). The knee position is shown graphically in Figure 4. The measurement is taken in cm with a soft tape measure from the medial and lateral femoral condyles to the midpoint of the patella (Figure 5). The technique for the lateral femoral condyle to the midpoint of the patella is shown graphically in Figure 6, which is repeated for the medial femoral condyle measurement. Proper location of these anatomical structures are palpated (McConnell, 1996) and marked on a piece of zinc tape by the physiotherapist (Herrington, 2002). A greater distance from the medial femoral condyle to the midpoint of the patella indicates lateral displacement of the patella.



**Figure 4:** 20° Knee flexion.



**Figure 5:** Medial and lateral femoral condyle landmarks (Chai, 2005).



**Figure 6:** Example of patella measurement taken from the midpoint of the patella to the lateral femoral condyle.

This technique was considered applicable for the study for the following reasons: it is prevalent in clinical practice, the time required to measure the patellar position is small and the technique's reliability when conducted by an experienced manual physiotherapist is thought to be acceptable. The aim of using this technique was to observe clinical changes of the patella alignment, specifically the lateral displacement of the patella throughout the treatment. The physiotherapist measured the patellar displacement of all participants prior to the treatment (before starting session 1), mid treatment (before starting session 6) and post treatment (24 hours following session 12). To control for measurement and recording errors, each measurement was taken twice and the average of the two was utilized. For the purpose of the data analysis, the pre and post measurements were analyzed.

The second component of the study involves the VAS. The VAS is extensively utilized in research. It has been validated and is considered a reliable tool used to measure individuals' perceived pain intensity (Joyce, Zutshi, Hrubes, & Mason, 1975; McCormack, de L. Horne, & Sheather, 1988). More specifically, a study measuring pain in rheumatology patients, reported a good test-retest reliability ( $r = 0.94$ ) (Ferraz et al., 1990). The VAS consists of a 10cm line, where the individual is asked to mark their pain level on the line where the ends are labelled as the extremes "no pain" and "pain as bad as it could possibly be".

The VAS was utilized in the study because it allows the user to highlight the real difference in magnitude of pain by calculating the difference in pain intensity taken at different time points (Price, Harkins, & Baker, 1987; Price, McGrath, Rafii, & Buckingham, 1983). The scale was not labelled 1-10 for the reason that the scale then



becomes a numerical rating scale (NRS), in which the labels could alter participant's responses (Scott & Huskisson, 1976). All participants completed four-VASs in terms of their knee pain during the following activities: pain they felt when ascending stairs within the last 24 hours, descending stairs within the last 24 hours, pain felt when standing from a seated position within the last 24 hours and worst pain ever felt within the last six weeks (Appendix C).

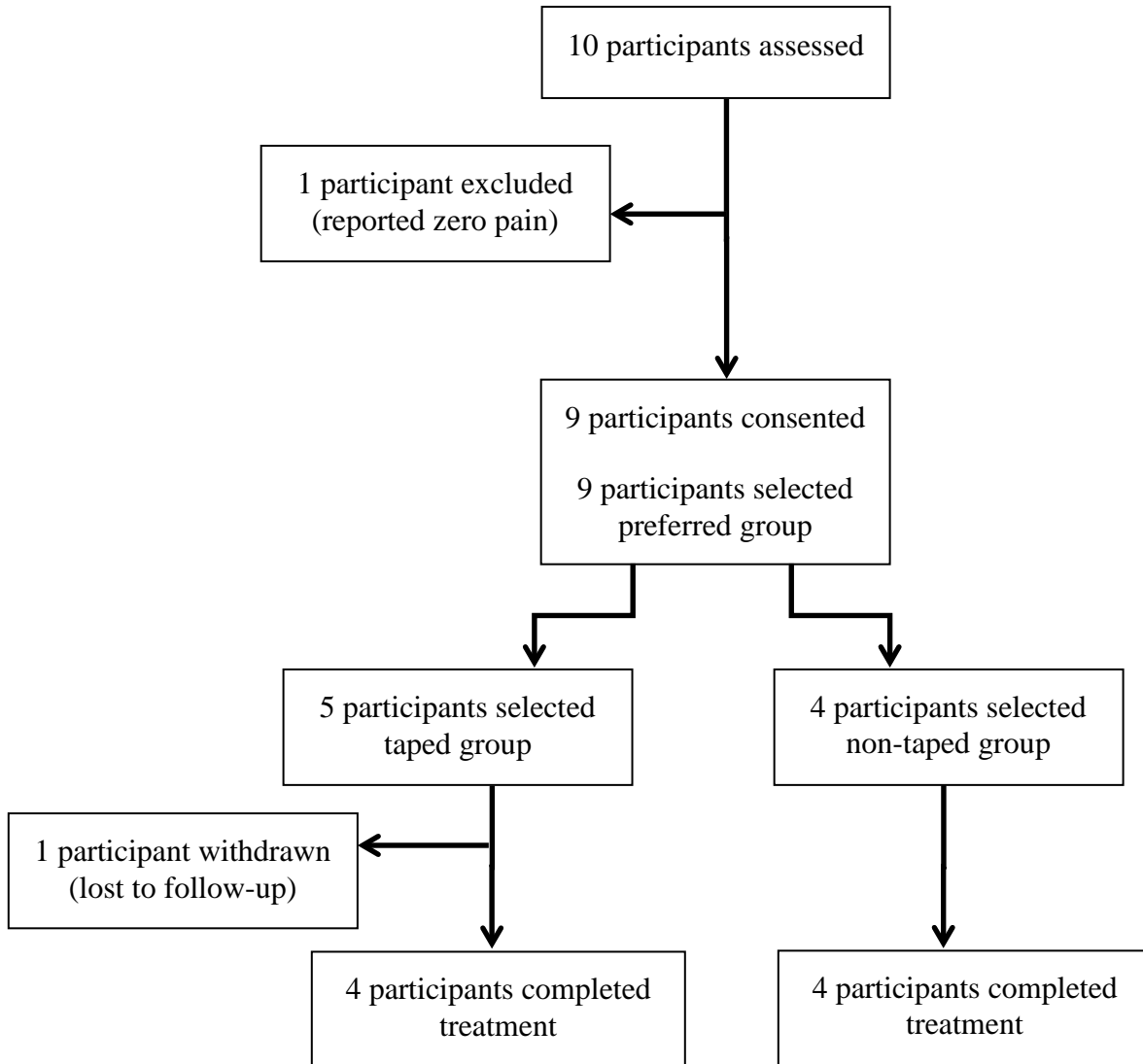
All participants completed the VASs at the three time stamps: prior to the treatment (before starting session 1), mid treatment (before starting session 6) and post treatment (24 hours following session 12). For the purpose of the data analysis, the pre and post treatment VAS scores were analyzed.

## **CHAPTER IV**

### **RESULTS**

#### 4.0 Participant Demographics

Between January and February 2016, 10 participants were assessed, 9 participants fulfilled the eligibility criteria and 8 participants completed the treatment (Figure 7).



**Figure 7:** Flow chart diagram of the progression of participants through the treatment

The demographic participant features for each group are displayed in Table 2.

There were 2 females in the taping group and 1 in the non-taping group.

**Table 2:** Demographic participant features of the taped and non-taped treatment groups

	Taped group ( <i>n</i> =4)		Non-Taped group ( <i>n</i> =4)	
	Mean	±SD	Mean	±SD
Age (years)	40.3	8.4	29	12
Height (cm)	174.8	22.3	174.8	3.9
Weight (kg)	85.9	22.8	84.2	28.1
BMI (kg/m <sup>2</sup> )	28.6	8.8	27.4	8.3
Pre Lateral score (cm)	8.8	1.0	8.7	0.7
Post Lateral score (cm)	8.9	1.0	8.8	0.7
Pre Ascending Stairs score (cm)	2.7	1.3	1.7	2.1
Post Ascending Stairs score (cm)	0.6	0.8	1.3	1.9
Pre Descending Stairs score (cm)	0.8	1.5	3.8	2.4
Post Descending Stairs score (cm)	0.1	0.2	1.0	0.8
Pre Standing from a seated position score (cm)	0.5	1.1	2.7	2.3
Post Standing from a seated position score (cm)	0.2	0.4	1.2	0.9
Pre Worst pain ever felt score (cm)	4.3	0.2	5.3	2.8
Post Worst pain ever felt score (cm)	2.0	0.9	3.0	1.8
Sex	2 female, 2 male		1 female, 3 male	

SD standard deviation

#### 4.1 SPSS Non-parametric tests

##### 4.1.1 Patella Measurement Results

Based on a Wilcoxon Sign Rank Test we reject the patella measurement hypothesis (1). The Wilcoxon Sign Rank Test showed no statistically significant difference between therapeutic exercise programs with or without medial knee taping on patellar displacement for PFPS.

Taped group:  $Z = -1.414$ ,  $p = 0.157$ , with a median lateral score rating of 8.7cm pre-treatment score and 8.8cm post-treatment score.

Non-Taped group:  $Z = -1.732$ ,  $p = 0.083$ , with a median lateral score rating of 8.8cm pre-treatment score and 8.9cm post-treatment score.

#### **4.1.2 Perceived Pain Results**

Based on a Wilcoxon Sign Rank Test we reject the perceived pain hypothesis. The Wilcoxon Sign Rank Test showed no statistically significant differences, between pre and post treatment either with tape or no tape in any pain conditions: (2) ascending stairs, (3) descending stairs, (4) standing from a seated position and (5) worst pain ever felt within the last six weeks.

##### Condition (2) ascending stairs:

Taped group:  $Z = -1.826$ ,  $p = 0.068$ , with a median pain score rating of 2.2 pre-treatment score and 0.4 post-treatment score.

Non-Taped group:  $Z = -0.447$ ,  $p = 0.655$ , with a median pain score rating of 1.2 pre-treatment score and 0.6 post-treatment score.

##### Condition (3) descending stairs:

Taped group:  $Z = -1.000$ ,  $p = 0.317$ , with a median pain rating of 0 pre-treatment score and post-treatment score.

Non-Taped group:  $Z = -1.826$ ,  $p = 0.068$ , with a median pain rating of 3.6 pre-treatment score and 1.1 post-treatment score.

##### Condition (4) standing from a seated position:

Taped group:  $Z = -1.000$ ,  $p = 0.317$ , with a median pain score rating of 0 pre and post treatment score.

Non-Taped group:  $Z = -1.604$ ,  $p = 0.109$ , with a median pain score rating of 0.4 pre-

treatment score and 0.3 post-treatment score.

Condition (5) worst pain ever felt within the last six weeks:

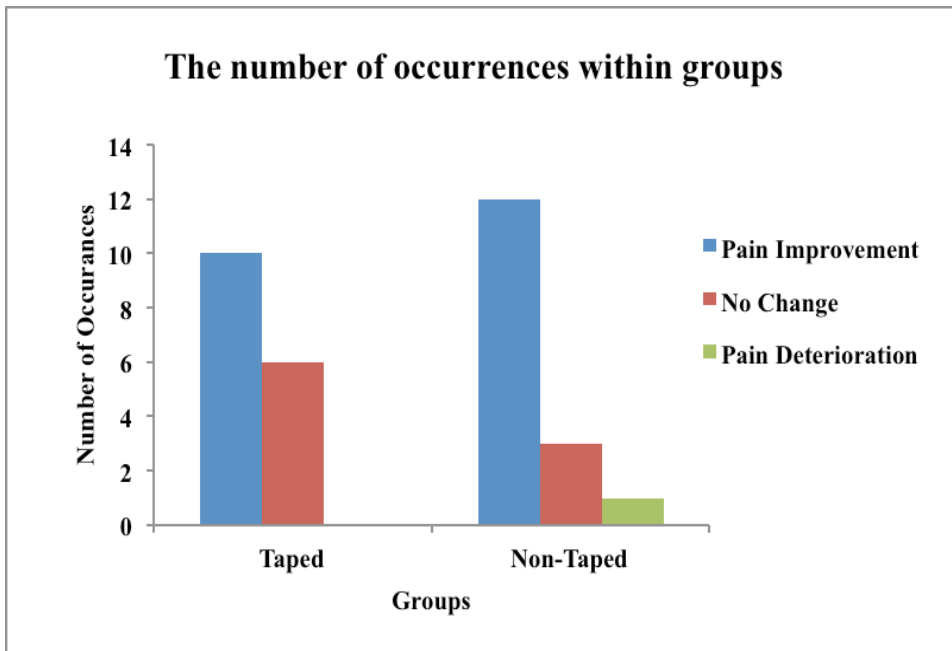
Taped group:  $Z = -1.826$ ,  $p = 0.068$ , with a median pain score rating of 4.3 pre-treatment score and 2.1 post-treatment score.

Non-Taped group:  $Z = -1.826$ ,  $p = 0.068$ , with a median pain score rating of 5.7 pre-treatment score and 2.6 post-treatment score.

## **4.2 Individual results**

Individual scores are plotted and qualitatively compared amongst groups as a result of insufficient statistical power to detect effects. When comparing the pre and post patellar measurements scores, 2 people in the taping group and 3 people in the non-taping group showed a decrease in lateral measurement scores, resulting in a positive patellar displacement to the medial side.

Figure 8 below illustrates the tallied number of occurrences of pain improvement, no change in pain and pain deterioration. These occurrences within groups stem from the VAS scores across all conditions (ascending stairs, descending stairs, standing from a seated position and worst pain ever felt within the last six weeks) (Figure 8).



**Figure 8:** The number of occurrences within each group: taped and non-taped. Pain improvement (blue), no change (red) and pain deterioration (green).

#### 4.2.1 Patella Measurement Case Results

Tables 3 and 4 provide information regarding the taping group. Table 3 provides the lateral patellar displacement. Table 4 provides the medial-lateral patellar difference (mm), where the lateral measurement was subtracted from the medial measurement. It is observed that all individuals in the taping group had a laterally displaced patella before treatment (Table 4) and 2 people had a positive lateral displacement after treatment (Table 3).

**Table 3:** Lateral patellar displacement (%) of the total knee length before and after treatment for taped group

	Taped Group - lateral patellar displacement (%)		
Participant	Before	After	Percent change (%)
1	48.28	48.17	-0.110
3	46.87	47.32	0.456
4	47.86	48.00	0.141
5	47.77	47.20	-0.577

*Note.* Percent change: positive value = lateral score increased (positive lateral displacement), negative value = lateral score decreased (negative lateral displacement).

**Table 4:** Medial-lateral patellar difference (mm) and percentage change (%) before and after treatment for taped group

	Taped Group – medial-lateral patellar difference (mm)		
Participant	Before	After	Percent change (%)
1	7.00	7.50	7.14
3	10.50	9.00	-14.29
4	8.50	8.00	-5.88
5	7.50	9.50	26.67

*Note.* Medial-lateral patellar difference (mm) = the lateral measurement subtracted from the medial measurement (positive value = lateral patellar displacement, negative value = medial patellar displacement). Percent change: positive value = greater medial-lateral difference (lateral measurement increased), negative value = smaller medial-lateral difference (lateral measurement decreased).

Tables 5 and 6 present the results for the non-taped group. Table 5 provides the lateral patellar displacement. Table 6 provides the medial-lateral patellar difference (mm), where the lateral measurement was subtracted from the medial measurement. It is observed that all individuals in the non-taping group had a laterally displaced patella before treatment (Table 6) and one individual in the non-taping group had a positive lateral displacement after treatment (Table 5).



**Table 5:** Lateral patellar displacement (%) of the total knee length before and after treatment for non-taped group

	Non-Taped Group - lateral patellar displacement (%)		
Participant	Before	After	Percent change (%)
2	46.75	47.13	0.382
7	48.31	47.67	-0.643
8	48.92	48.81	-0.118
9	46.71	46.45	-0.257

*Note.* Percent change: positive value = lateral score increased (positive lateral displacement), negative value = lateral score decreased (negative lateral displacement).

**Table 6:** Medial-lateral patellar difference (mm) and percentage change (%) before and after treatment for non-taped group

	Non-Taped Group – medial-lateral patellar difference (mm)		
Participant	Before	After	Percent change (%)
2	13.00	11.50	-11.54
7	6.00	8.50	41.67
8	4.00	4.50	12.50
9	11.00	12.00	9.09

*Note.* Medial-lateral patellar difference (mm) = the lateral measurement subtracted from the medial measurement (positive value = lateral patellar displacement, negative value = medial patellar displacement). Percent change: positive value = greater medial-lateral difference (lateral measurement increased), negative value = smaller medial-lateral difference (lateral measurement decreased).

#### 4.2.2 Perceived Pain Score Case Results

A comparison of pain conditions before and after treatment for the taped and non-taped group is displayed in Table 7 and 8 respectfully. These results are also graphed in Appendix E. The before and after values for each ADL stem from the VASs, in which the distance was measured in cm from the start of the VAS labelled “no pain” to the individuals’ marked value. This value was divided by the length of the VAS and multiplied by 100 to represent a percentage score. From this percentage score,

individual's percentage changes were calculated.

It is observed that there was an overall decrease in pain for all individuals experiencing pain during the ADL (ascending stairs, descending stairs, standing from a seated position and worst pain ever felt within the last six weeks) in the taped group (Table 7).

**Table 7:** Comparison of perceived pain percentage scores before and after 4-week treatment, and the pain percentage change for taped group

Taped Group - Perceived Pain Reported (%)												
Par.	Ascending stairs		% change	Descending stairs		% change	Standing from a seated position		% change	Worst pain ever felt within the last 6 weeks		% change
	Before	After		Before	After		Before	After		Before	After	
1	21.1	8.1	61.5	30.9	4.1	86.8	21.1	8.1	61.5	43.9	8.1	81.5
3	46	17.6	61.8	0	0	0	0	0	0	46.2	17.6	61.8
4	16.8	0	100.0	0	0	0	0	0	0	41.2	30.3	26.5
5	23.5	0	100.0	0	0	0	0	0	0	42.0	24.4	42.0

It is observed that there was an overall decrease in pain for all individuals experiencing pain during the descending stairs, standing from a seated position and worst pain ever felt within the last six weeks in the non-taped group. The ADL ascending stairs, increased for participant 7 (Table 8).

**Table 8:** Comparison of perceived pain percentage scores before and after 4-week treatment, and the pain percentage change for non-taped group

	Non-Taped Group - Perceived Pain Reported (%)											
	Ascending stairs		% change	Descending stairs		% change	Standing from a seated position		% change	Worst pain ever felt within the last 6 weeks		% change
Par.	Before	After		Before	After		Before	After		Before	After	
2	0	0	0	21.8	0	100.0	0	0	0	43.7	17.6	59.6
7	24.6	40.2	<b>-63.3</b>	65.6	14.8	77.5	45.1	18.0	60.0	79.5	52.5	34.0
8	42.6	13.1	69.2	50.0	16.4	67.2	47.5	18.9	60.3	69.7	34.4	50.6
9	0	0	0	13.1	7.4	43.8	15.6	11.5	26.3	17.2	13.9	19.0

**CHAPTER V**  
**DISCUSSION**

## **5.0 Study overview: purpose, hypotheses and findings**

The aims of this study were to evaluate the impact of the McConnell medial taping technique commonly used in clinical settings on i) patellar alignment and ii) perceived knee pain in patients with PFPS.

It was hypothesized (1) that the implementation of a four-week therapeutic exercise program with knee taping for PFPS would improve the patellar alignment to a greater extent than the therapeutic exercise program on its own. According to the Wilcoxon Sign Rank Test, no significant change in patellar alignment with tape was detected (hypothesis 1, refuted).

It was also hypothesized that the implementation of a four-week therapeutic exercise program with knee taping for PFPS would reduce the perceived pain intensity to a greater extent than the therapeutic exercise program on its own when (2) ascending stairs, (3) descending stairs, (4) standing from a seated position and (5) worst pain ever felt within the last six weeks. According to the Wilcoxon Signed Rank Test no significant change in patellar alignment with tape was detected (hypothesis 2, 3, 4 and 5 refuted).

Given the limited sample size, it is highly likely that the non-parametric tests lack sufficient power. Therefore, individual results were plotted and compared on a case-by-case basis. By plotting individual results, lateral displacement of the patella after treatment were observed in 1 individual in the taping group and 2 individuals in the non-taping group. Furthermore, the overall perceived pain during the four activities was reduced after treatment in both groups (taping vs. no taping) (Appendix E).

## **5.1 Patellar Alignment**

All individuals in the study were diagnosed with PFPS. The positive changes in patellar alignment pertaining to the lateral displacement in both groups were minimal, yet the pre patellar alignment measurement scores indicated that all individuals had a laterally positioned patella: the measurement taken from the medial condyle to the mid-point of the patella was greater than the lateral condyle to the mid-point of the patella. This finding corresponds with McConnell (1986) and Mizuno et al. (2001) who have stated that PFPS is associated to a laterally displaced patella. The rationale behind this theory is that there are greater lateral forces acting on the patella from the VL muscle, as a result of weakness in the VMO muscle (Halabchi et al., 2013).

Limited studies exist on patellar alignment within PFPS populations and more importantly, studies addressing normal versus abnormal patella positions are controversial. Grelsamer, Newton and Staron (1998), believe that the reason behind such controversy is because the word “normal” is ambiguous. First, “normal” can be interpreted as a measurement that “falls within two standard deviations of the mean” (Grelsamer, 2005, p.64). Second, “normal” can be defined as something that is common and third, medically it can imply that there is no pain, death, deformity or disability (Grelsamer, 2005; Grelsamer, Newton, & Staron, 1998). Given that our study included all individuals with knee pain, the third definition of normality described by Grelsamer (2005) and Grelsamer, Newton, & Staron, (1998) does not apply. Consequently, normality described as something that is common (Grelsamer, 2005; Grelsamer et al., 1998) could be applicable to the current study since there was a common finding with the pre patellar alignment measurements for all participants that indicated laterally positioned

patellas.

### **5.1.1 Asymptomatic Alignment**

Common or normal patella positioning within a healthy population has been disputed in the literature, which may in fact present controversy when determining differences between asymptomatic and symptomatic patellar positions. McConnell, describes an optimal positioned patella as one that is situated equidistant between the two condyles with the knee flexed at 20° (McConnell, 1996, 1986). Despite this statement, normative data for these measurements have yet not been defined (Powers, Mortenson, Nishimoto, & Simon, 1999; Wilson, 2007), which presents uncertainties when evaluating the patellar alignment in a clinical setting.

Early research conducted by Delgado-Martins (1979), studied the patella position in asymptomatic subjects using a computerised tomographic scanning system (CT). He discovered that when the knee is in a relaxed position the patella is situated laterally and as the knee starts to flex the patella gradually moves centrally (Delgado-Martins, 1979). In the photograph “Computerized tomography of fully extended knee with quadriceps relaxed. Figure 1 – Distal cut” provided by Delgado-Martins (1979, [p.443](#)), one can see the lateral positioned patella in a relaxed position. The results from more recent research using dynamic MRI during weight bearing stance with an asymptomatic population are congruent with this finding, in which a lateral positioned patella was detected in the early stages of flexion (Tennant et al., 2001). That being said, a laterally displaced patella is not an uncommon finding in asymptomatic populations. However, these populations are believed to be healthy and free from pain, muscle weakness and or anatomical

abnormalities at the PFJ (Aminaka & Gribble, 2005), which, in any case, does not define a pathologic patella position/orientation or tracking. Furthermore it remains unclear how these variables are associated with pathology or symptoms.

### **5.1.2 Symptomatic Alignment**

Grelsamer, Newton, and Staron (1998) and MacIntyre, Hill, Fellows, Ellis and Wilson (2006) studied the patellar alignment in a symptomatic population. Comparable to the symptomatic inclusion criteria listed by Grelsamer et al. (1998), the current study included individuals with anterior knee pain, and positive results on the following clinical tests: Clarke's Sign Test (examining patellar compression, tilt and tenderness) and Step Up Test (examining crepitus and signs of instability which include symptoms of knee giving away or giving out). Contrary to the Grelsamer et al. (1998) criteria, a Q-angle measurement was not used in the study due to the fact that it remains a questionable measure for PFPS (Caylor et al., 1993; Fairbank et al., 1984; Thomeé et al., 1995b). More specifically, the Q-angle relationship between PFP sign and symptoms has been inconsistent (L. Livingston, 1998) and furthermore researchers Lankhorst, Bierma-Zeinstra, & van Middelkoop (2012) suggest that this measurement alone cannot be considered a risk factor for PFPS. In other words, this angle is not likely correlated to the pathogenesis of PFPS. Grelsamer et al. (1998) and MacIntyre et al. (2006) both found a significant patellar alignment difference in individuals with PFPS compared to a control group using MRI. MacIntyre et al. (2006) reported an average laterally displaced patella of 2.25mm ( $p = 0.049$ ) at  $19^\circ$  of knee flexion, and Grelsamer et al. (1998) reported a significant laterally positioned patella ( $p < 0.01$ ) with an average lateral displacement of



6mm during 0° knee extension. While the knee angle used to measure the patellar alignment in this study differed from that of Grelsamer et al. (1998) who measured the alignment in full extension at 0°, a laterally positioned patella remained consistent amongst all participants in the current study with the knee flexed at 20°.

Limited studies exist on the long-term patellar alignment effects using the McConnell medial taping technique. However, a number of studies suggest that taping mechanisms can stimulate a neuromuscular response, in which the cutaneous mechanoreceptors located in the skin increase afferent feedback to the central nervous system (Campolo et al., 2013; Chang, Chou, Lin, Lin, & Wang, 2010; Kneeshaw, 2002; Thelen, Dauber, & Stoneman, 2008), resulting in pain reduction (Kumbrink, 2014; Thelen et al., 2008). This physiological taping mechanism, decreasing pain and facilitating muscle contraction, helps explain how the combination of taping and exercise improves muscle activity and function (Akbaş, Atay, & Yüksel, 2011; Kuru, Yalman, & Dereli, 2012). Having said this, individuals with PFPS using the taping application could enhance their VMO muscle strength as a result of the neuromuscular response. Thus, strengthening the VMO musculature can promote proper patellar alignment, which may explain how taping can lead to long-term improvements in patellar alignment. Nonetheless, further research is required on the long-term effects of using the McConnell medial taping technique.

## **5.2 Manual patella alignment assessment**

The patella alignment assessment was developed by McConnell (1986) and improved by Herrington (2002). According to Smith, Davies, et al. (2009) the method

that Herrington (2002) used to assess the medial-lateral patellar position with a piece of zinc tape to measure the distances has better inter-tester reliability and criterion validity. For this reason, this method was utilized in our study. Nonetheless, the results of our study affirmed that very little difference in displacement was detected when comparing pre-treatment and post treatment scores within each group.

The current study did not include a control group with purely taping; therefore, the effectiveness of this component on its own cannot be identified. The reason behind the study's design without this particular control group is that the university ethics board disagreed with the possibility that symptomatic individuals would not receive ideal PFPS treatment. Effective treatment for PFPS provided in a clinical setting includes exercise therapy, which is strongly supported in the literature (Bolgia & Boling, 2011; Bolgia & Malone, 2010, 2010; Crossley et al., 2002; Fagan & Delahunt, 2008; Gielen & Sleet, 2003; Harvie et al., 2011; Heintjes et al., 2003; Wyss & Patel, 2012).

### **5.3 Pain Measurement**

The pain data observed in the current study is comparable with past results reported by Kowall et al. (1996). In particular, a significant decrease in pain frequency during ADL post-treatment was observed using a visual 10-point analog scale (Kowall et al, 1996). Although the ADL are not specified in their study, ADL can be described as activities conducted daily and independently. We assumed that these include activities used in the current study such as ascending stairs, descending stairs and standing from a seated position. Their sample consisted of a symptomatic PFP population ( $n=25$ ) in which one group underwent exercise ( $n=13$ ) and the other exercise and taping ( $n=12$ ).

Their taping method consisted of the McConnell medial taping technique, the same method used in this study. Both groups showed a statistically significant decrease in pain frequency during ADL ( $P<0.05$ ) (Kowall et al., 1996). Notably the Kowall et al. (1996) study focused on muscle recruitment, muscle strength and pain intensity while ours concentrated on the patellar displacement and pain intensity.

Wilson, Carter and Thomas (2003) reported that patellar taping techniques including that of McConnell's resulted in a significant degree of pain relief compared to non-taped when performing the step down exercise. Similarly, our study incorporated the step down exercise in the treatment program and individuals marked their perceived pain on the VAS when descending stairs. Only one individual in the taping group reported pain during this activity in which the pain score decreased in total by 26.8% post treatment. The results of this study along with several others (Bockrath et al., 1993; Christou, 2004; Kowall et al., 1996; Warden et al., 2008; Whittingham, Palmer, & Macmillan, 2004) continue to show that the McConnell medial taping technique minimizes knee pain in individuals with PFPS.

Improvements in perceived pain were observed in the current study for the majority of individuals in both the taping and non-taping groups. These observations would suggest that the exercise program developed for PFPS seemed to be effective in decreasing pain amongst this patient population. Despite these encouraging results, Collins et al. (2013) reported that 40% of individuals with PFPS experienced unfavourable recovery up to one year following treatment, regardless of the intervention. It is worth noting that the perceived knee pain of individuals in the current study was reduced during and after the intervention. However, according to Collins et al. (2013) it

can be expected that symptoms would reappear months following PFPS treatment. This raises the concern that the original cause of the syndrome may not be properly addressed even though relief might persist with adherence to the therapy protocol.

#### **5.4 Patellofemoral Joint Area**

The insignificant patellar alignment results in the current study present uncertainty regarding the effects of the McConnell medial taping technique. More specifically, the observed decrease in knee pain within the symptomatic population with and without the McConnell medial taping technique could possibly result from underlying PFJ mechanisms.

A recent study investigated the correlation between patellofemoral alignment and contact area in pain free subjects (Freedman, Sheehan, & Lerner, 2015). In this study, the biomechanical properties of the patellofemoral unloaded joint via MRI screening, were characterized by an increased patellofemoral cartilage contact area ( $\text{mm}^2$ ) as the knee flexed from full extension ( $0^\circ$ ), to moderate flexion ( $60^\circ$ ) and to deep flexion ( $140^\circ$ ) (Freedman et al., 2015). In other words, a direct relationship between cartilage contact area and knee flexion was found as the cartilage contact area increased with greater knee flexion (Connolly, Ronsky, Westover, Küpper, & Frayne, 2009; Freedman et al., 2015). This finding corresponds with other studies showing the same relationship (Besier et al., 2005; Csintalan, Schulz, Woo, McMahon, & Lee, 2002; D'Agata, Pearsall, Reider, & Draganich, 1993). Additionally, Freedman et al. (2015) recorded the medial and lateral facets of the patella contacting the femoral condyles during deep flexion ( $140^\circ$ ) where the lateral facets of the patella showed a greater contact area ( $\text{mm}^2$ ) compared to the medial

facets. Having said this, the greater contact area experienced by the lateral facets of the patella during deep flexion (Freedman et al., 2015) is an indication that the contact area shifts during patellar tracking and that the pressure applied may be lower to compensate for higher load. The latter can be explained by the stress equation  $\text{pressure} = \text{force} / \text{area}$ . Essentially, if the force applied remains the same yet the contact area increases, the stress or pressure applied to the surface will be lower.

In terms of contact area in a symptomatic population, Heino-Brechter and Powers (2002) reported that individuals afflicted with PFP have a lower contact area in an unloaded joint compared to healthy subjects. This would make sense given that a smaller contact area is likely associated with higher pressures. According to Besier et al. (2005), there can be an expected 24% contact area increase when a healthy knee joint is loaded. The researchers conclude that contact area within the PFJ should be measured under loaded conditions to properly account for the PFPS pathology such as cartilage deformation and changes in patellar alignment and tracking (Besier et al., 2005).

Interestingly, Connolly et al. (2009) studied contact area in healthy and individuals with PFPS under load and found that the symptomatic population experienced greater contact area during 15° to 30° of knee flexion. It is between these angles where the patella enters the trochlear groove of the femur. Connolly et al. (2009) suggest that when the patella is maltracking, the same area of tissue could essentially be exposed to a longer than normal load thereby increasing PFP. Thus, while our study utilized the McConnell medial taping technique to assist in pulling the patella medially, the contact area during patellar tracking may have shifted or completely changed contact points. This may further explain why the symptomatic individuals experienced a decrease in

perceived pain.

It has been proposed by Powers, Ward, Chan, Chen and Terk (2004) that increasing the PFJ contact area distributes the force over a greater surface area, producing reduced pain outcomes. The authors found in a PFP population that wearing a knee brace significantly increased the contact area during 0°, 20°, 40° and 60° of flexion with 25% BW. Furthermore, though slight changes in lateral patellar displacements were noted, pain measures were significantly reduced (Powers et al., 2004). Therefore, changes in PFJ contact area from knee bracing may have greater influences on perceived knee pain than that of patellar alignment (Powers, Shellock, et al., 1999; Powers et al., 2004), suggesting that patellar alignment may not be the most valid outcome measure for PFPS. Since the external patellar taping technique could have comparable effects to that of bracing, a similar study with tape, under load, within the PFPS population is required.

## **5.5 Limitations**

A number of limitations should be acknowledged in the study. First and foremost, the sample size was small. The reasons for low recruitment numbers included: altering original recruitment location from therapeutic clinics due to unforeseen staffing changes, difficulty with transportation to and from the University for physiotherapy assessments and availability during the evenings. Due to the limited sample size, the statistical analysis is considered to be underpowered resulting in insufficient statistical power to detect effects. The non-parametric statistical findings should be interpreted cautiously as there is possibility of type I error (failure to accept the null hypothesis when it is true) or type II error (failure to reject the null hypothesis when it is not true). A larger sample size

would be necessary in order to validate the results and ensure a representative distribution of the PFP population.

Secondly, there may have been limitations in the method used to calculate patellar alignment. The lateral patellar displacement measurement described by McConnell (1996) and improved by Herrington (2002) was used in the study because it is clinically recognized and considered reliable when experienced manual physiotherapists conduct the measurement (Herrington, 2002). The experienced physiotherapist that conducted the assessments in the study palpated around the injured knee to find the particular landmarks: medial and lateral condyles of the femur and the midpoint of the patella. Once the landmarks were found, the physiotherapist measured the distance of the femoral condyles to the midpoint of the patella. This procedure was conducted a second time with re-palpation of the landmarks and the average of the two measurements was utilized. Although this technique is widely accepted and employed in clinical settings, this manual measurement is nevertheless limited. The precise measurement of the patella position was based on palpation. Palpation of soft tissue, in some instances could influence the condyle landmarks.

Normative data of the manual measuring technique have not been established (Wilson, 2007), presenting a limitation in itself. Furthermore, because the current study did not make use of the gold standard MRI and CT scanning techniques to assess patellar positions, direct comparisons to other studies was not possible. A technical tool such as MRI would have allowed for more precise observations of the patella displacement and could essentially locate the patella placement from the trochlear groove, where further observations could be made. These observations could include, evaluating the space

between the trochlear groove and the patella and determining whether or not the cartilage thickness is correlated with the amount of perceived pain scored by individuals with PFPS. Using MRI could have also confirmed if the patient population had patellar malalignment. Although a laterally positioned patella seems to be a common occurrence for individuals with PFPS, detecting patellar malalignment in individuals with PFPS within a clinical assessment remains unknown.

Randomized groups were not present in the current study due to ethical constraints. Thus, all participants underwent the same exercise program yet were asked to select a preferred group, either with the McConnell medial taping technique or without. This procedure emerged from similar patient-centred decisions within a clinical setting but it may have introduced selection bias in this study. Comparing like groups in a fair manner is challenging given the fact that the individual selected their preferred treatment approach. In addition, there's a possibility that response bias exists in this study, as a result of the individual knowing the purpose of the intervention. For example, there might be a tendency to report a decrease in pain throughout the intervention, or pressure to record pain on all the VASs corresponding to the ADL when an individual may not have had pain during that particular activity.

Lastly, due to ethical concerns regarding proper treatment for PFPS (i.e exercise prescription), observing the effects of the McConnell medial taping technique on its own was not possible in this study. The absence of this control group limits the data available surrounding the effects of taping on its own as it relates to patellar displacement and perceived knee pain during ADL such as: ascending stairs, descending stairs and standing from a seated position.



## **5.6 Future Directions**

Future studies should focus on the patellar alignment component given the fact that asymptomatic and symptomatic patellar alignment differences remain unclear. Observing the patellar alignment between healthy and non-healthy knees would confirm the malalignment's theory and its relationship to PFPS. The study design would consist of a t-test including two groups: individuals with PFPS and without PFPS. Ideally three physiotherapists would be involved in the study: one would perform the initial assessment for the symptomatic group, which would consist of diagnosing individuals with PFPS. The other two physiotherapists would be blinded to the groups and would conduct the patellar measurements. By having two physiotherapists' measure and record the patellar measurements, the inter-rater reliability could be tested of the proposed Herrington (2002) clinical patellar measurement method. Although evidence regarding patellar alignment and PFPS is warranted, additional studies are required to fully understand the factors that play a role in decreasing knee pain in individuals with PFPS. The effects of the McConnell medial taping technique should be further explored on a larger scale via a larger sample size to ensure proper representation of this symptomatic population. Furthermore, PFJ contact area is an important mechanical effect required to understand the relationship associated to this prevalent treatment technique.

Future research could look at the correlation between PFJ contact area and perceived knee pain with and without medial knee taping at various knee angles. These types of interventions within a symptomatic population have not yet been extensively researched, and would greatly contribute to the validity of using the taping technique for treating PFPS.

In sum, the complexity of this syndrome challenges therapeutic interventions, as there remains no single definitive cure or treatment for patients diagnosed with PFPS. In order to prevent the development of OA and the negative health effects of living in continuous discomfort, it is important to ensure patients with this syndrome are receiving appropriate treatment. One way to accomplish this is to continue to explore the popular therapeutic treatment techniques prescribed for PFPS and more importantly, to further study the underlying mechanisms that influence PFP.

**CHAPTER VI**  
**CONCLUSION**

## **6.0 Conclusions**

In conclusion, this study reaffirmed that exercise therapy controls and reduces knee pain in a symptomatic PFPS population. Additionally, no additional benefits were noted when combining taping with the exercise program at least in our subject pool but further research with a larger sample is required to draw firm conclusions on the effectiveness of the combined therapy. Though the McConnell medial taping technique is thought to improve patellar alignment, further clinical assessment of the patella alignment in individuals with PFPS is necessary.

Although not measured in this study, it is believed that the knee taping may have a mechanical influence, which changes the PFJ contact area, potentially decreasing overall pressure applied to the damaged tissue. However because both groups showed a decrease in pain scores this assumption requires further investigation. Ultimately, future studies in this area would help clinical treatment implementation.

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## **APPENDICES**



# Participants Needed

Do you experience **knee pain**?  
If so, you may qualify as a participant in this study!



We are looking for males and females with knee pain when ascending, descending and or standing from a seated position who are willing to undergo exercise therapy with or without tape for 4 weeks.

If interested please contact:

Alicia Canning  
(705)-870-4527  
ax\_canning@laurentian.ca

## Appendix B: Participant Information and Consent Form



### Participant Information and Consent Form

#### **Study Title: The effect of medial knee taping on the patella alignment**

Thank you for your interest in the study. The purpose of this research is to identify the effects of patella alignment in individuals with patellofemoral pain syndrome throughout an exercise program with and without knee taping.

#### **Experiment:**

If you agree to participate, non-identifying information such as your sex, age, height, weight and body mass index (BMI) will be collected prior to the start of the testing.

Following this, you will be asked to decide if you wish to wear knee tape during the physiotherapy treatment period or not (Group 1 – taped, Group 2 – not taped). It is important to note that your decision will not affect your physiotherapy treatment plan in anyway (except for the addition or removal of tape). Also if you wish to switch groups or withdraw from the study, you are permitted to do so at any point and time.

An exercise program recommended to treat PFPS will be prescribed by the physiotherapist and presented to both groups. This exercise program contains a strengthening and flexibility component and will be conducted at the physiotherapy clinic 3 times per week for 4 weeks (a total of 12 sessions). This should take a maximum of 40 minutes.

Measurements of you knee alignment will be taken 3 times (prior to session 1 and session 6 and 1 hour after session 12) with a soft measuring tape and goniometer. Also during this testing time, you will be asked to complete a short pain scale questionnaire indicating your level of perceived pain within the last 24hours when ascending/descending stairs and standing from a seated position. This should take a maximum of 5 minutes.

No follow-up beyond the 4 weeks is necessary for this study.

**Risks and Benefits:**

There are no known risks associated with this study. In fact, the physiotherapist treats PFPS individuals with the exercise program mentioned above. The choice to wear knee tape or not during this therapy is at your discretion.

In terms of benefits, your treatment method may correct patella alignment resulting in a decrease of perceived knee pain, which may allow you to better complete your activities of daily living. Through your participation, you will contribute to new findings regarding patellofemoral pain syndrome and treatment methods.

**Confidentiality:**

The information obtained during this research will be treated as privileged and confidential. The information will be kept secured with a password on one portable computer and any hard copies collected will be stored in a locked drawer at the physiotherapy clinic. All data/information collected will be kept secure for 5 years where it will then be digitally and manually shredded. Only the researcher (Alicia Canning) and supervisor (Dr. Sylvain Grenier) will have access to the information.

**Right to Withdraw:**

You can choose to switch groups or withdraw at any time without consequence of any kind. The choice to withdraw or switch will not impact current or future treatments. If you choose to withdraw, your data and or any information collected will be removed from the database.

**Contacts:**

If you have any questions or concerns about the research purpose, design or any other element, feel free to contact the researcher Alicia Canning by email at [ax\\_canning@laurentian.ca](mailto:ax_canning@laurentian.ca) or the research supervisor Dr. Sylvain Grenier telephone: (705) 695-1151 ext. 1095 or toll free at 1-800-461-4030 ext. 1095 or via email [sgrenier@laurentian.ca](mailto:sgrenier@laurentian.ca).

If you have any questions regarding the ethical aspect of this research please contact the Laurentian University Research Office, telephone: 705-675-1151 ext. 2436 or toll free at 1-800-461-4030 ext. 2436 or via email [ethics@laurentian.ca](mailto:ethics@laurentian.ca).

**Additional Information**

- I will NOT be allowed to participate in this study if:
  - a) I have had knee surgery within the last year
  - b) I have severe or moderate Arthritis in the knee

- c) I have cortisol/steroid injections to the knee within the last 6 months
- d) I have peripatellar bursitis, tendinitis, plica syndrome or any kind of rare occurring conditions/pathologies
- e) I'm taking anti-inflammatory medication
- f) I have had past allergenic tape reactions

**By signing below I am indicating that:**

- I have read and understood this letter of information and consent form
- I am aware that the purpose of the study is to observe the effects on patellar alignment given my treatment method proposed by my physiotherapist
- I realize that I can withdraw at any time without consequence of any kind
- I realize that I can contact any of the people identified in this letter if I have questions, concerns, or complaints
- I realize that my data will be coded and kept confidential
- I have been given the opportunity to ask questions about this study

I, the undersigned, understand the project, its implications (benefits and risks) and I agree to participate.

<b>Participant's Name &amp; Signature</b>	<b>Date</b>
Printed:	
Signature:	

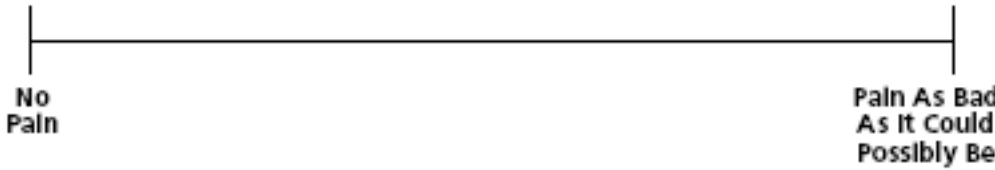
<b>Researchers Signature</b>	<b>Date</b>
Printed:	
Signature:	

A summary report of the study's results will be posted in the Physiotherapy Clinic.  
If you wish to obtain the study's results via e-mail, please provide your address below:

Email:
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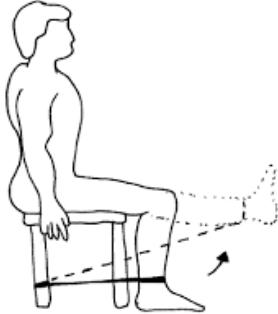
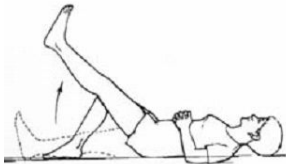
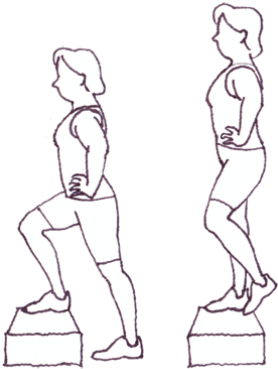
## Appendix C: Measures

**Participant #**      – Left or Right knee


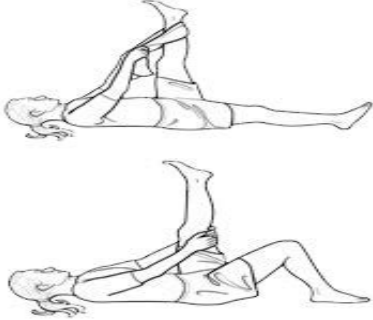
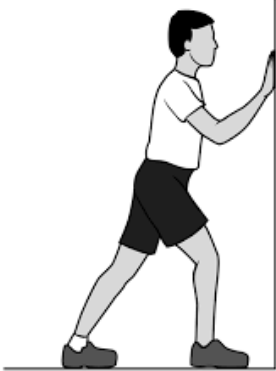

<b>Age:</b>	<b>Height:</b>	<b>Weight:</b>	
<b>Session _ :</b> a) ascending stairs b) descending stairs c) standing from a seated position			
<p><i>Visual Analog Scale (VAS)†</i></p> 			
Measurements:			
Lateral (cm)	Medial (cm)	Lateral Av	
Lateral (cm)	Medial (cm)	Medial Av	

## Appendix D: Exercises

### Strengthening Exercises – 3 sets of 10

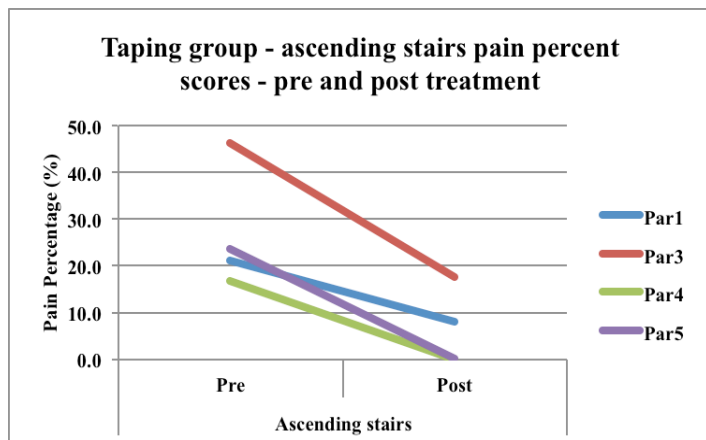
<p>1. Double leg squat (15-20°)</p> 	<p>2. Seated knee extension</p> 	<p>3. Straight leg raises</p> 	<p>4. Step up/step down exercises</p> 
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### Flexibility exercises – 3 times with 30-second hold

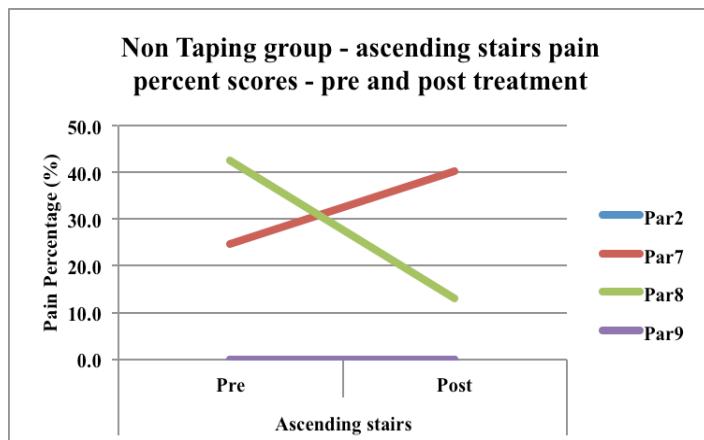
<p>1. Quadriceps</p>  <p>WorkoutLabs.com</p>	<p>2. Hamstrings</p> 	<p>3. Iliotibial band stretch (ITB)</p> 	<p>4. Gastrocnemius</p> 
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## Appendix E: Individual Pain Scores

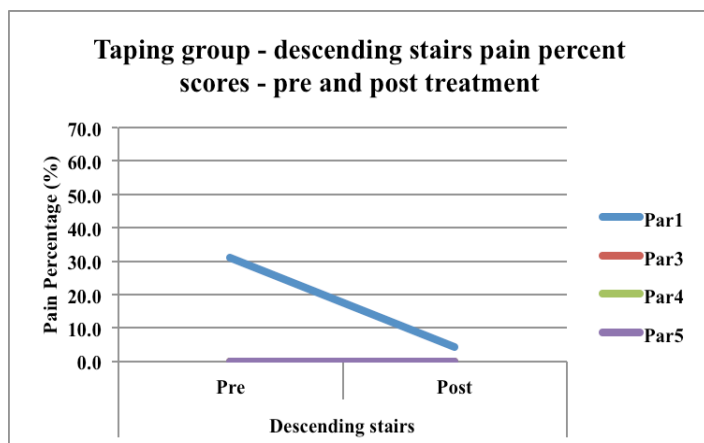
The pain conditions are individually presented through Figures 1-8 comparing the results of the taped group vs. non-taped group.



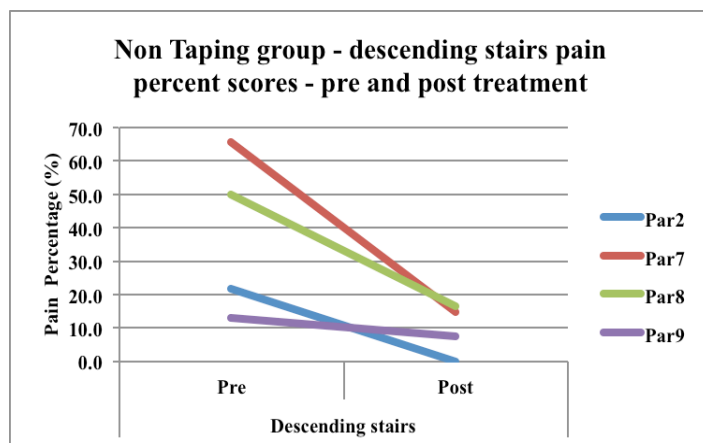
**Figure 1:** Taped group, pre and post perceived pain scores (%) for pain condition; ascending stairs. Participant 1 (blue), participant 3 (red), participant 4 (green) and participant 5 (purple).



**Figure 2:** Non-taped group, pre and post perceived pain scores (%) for pain condition; ascending stairs. Participant 2 (blue) is not visible on graph, reported 0% pain pre and post, participant 7 (red), participant 8 (green) and participant 9 (purple) presented on graph reported 0% pain pre and post.

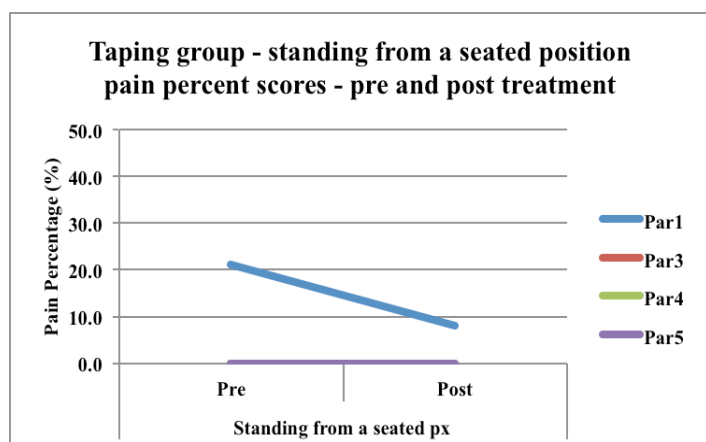


**Figure 3:** Taped group, pre and post perceived pain scores (%) for pain condition; descending stairs. Participant 1 (blue), participant 3 (red) and participant 4 (green) not visible on graph, reported 0% pain pre and post and participant 5 (purple) also reported 0% pain pre and post.

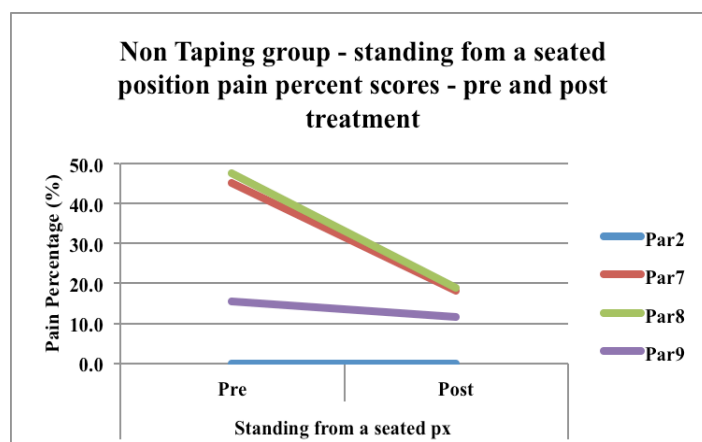


**Figure 4:** Non-taped group, pre and post perceived pain scores (%) for pain condition; descending stairs. Participant 2 (blue), participant 7 (red), participant 8 (green) and participant 9 (purple).

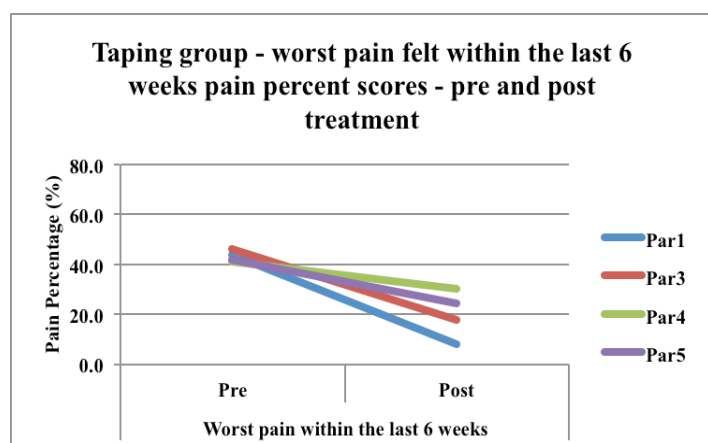




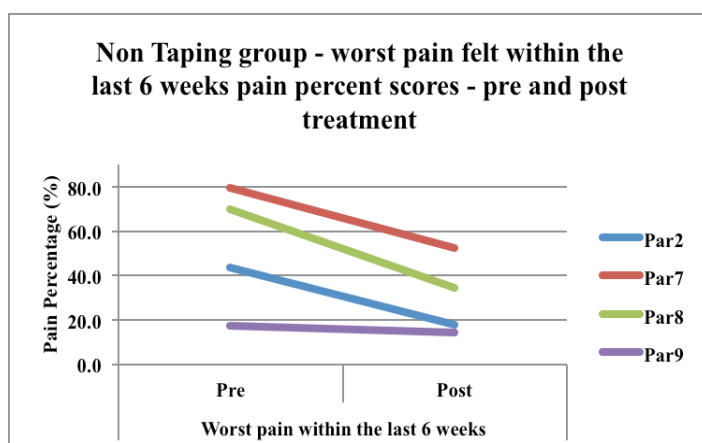
**Figure 5:** Taped group, pre and post perceived pain scores (%) for pain condition; standing from a seated position. Participant 1 (blue), participant 3 (red) and participant 4 (green) not visible on graph, reported 0% pain pre and post and participant 5 (purple) also reported 0% pain pre and post.



**Figure 6:** Non-taped group, pre and post perceived pain scores (%) for pain condition; standing from a seated position. Participant 2 (blue), presented on graph reported 0% pain pre and post, participant 7 (red), participant 8 (green) and participant 9 (purple).



**Figure 7:** Taped group, pre and post perceived pain scores (%) for pain condition; worst pain felt within the last 6 weeks. Participant 1 (blue), participant 3 (red), participant 4 (green) and participant 5 (purple).



**Figure 8:** Non-taped group, pre and post perceived pain scores (%) for pain condition; worst pain felt within the last 6 weeks. Participant 2 (blue), participant 7 (red), participant 8 (green) and participant 9 (purple).

## Appendix F: Research Ethics Board Approval



### APPROVAL FOR CONDUCTING RESEARCH INVOLVING HUMAN SUBJECTS

Research Ethics Board – Laurentian University

This letter confirms that the research project identified below has successfully passed the ethics review by the Laurentian University Research Ethics Board (REB). Your ethics approval date, other milestone dates, and any special conditions for your project are indicated below.

TYPE OF APPROVAL / New **X** / Modifications to project / Time extension

<b>Name of Principal Investigator and school/department</b>	Alicia Canning, School of Rural & Northern Health, supervisor, Sylvain Grenier, Human Kinetics
<b>Title of Project</b>	The effect of medial knee taping on the patella alignment
<b>REB file number</b>	2015-11-12
<b>Date of original approval of project</b>	January 26, 2016
<b>Date of approval of project modifications or extension (if applicable)</b>	
<b>Final/Interim report due on:</b> (You may request an extension)	January 26, 2017
<b>Conditions placed on project</b>	

During the course of your research, no deviations from, or changes to, the protocol, recruitment or consent forms may be initiated without prior written approval from the REB. If you wish to modify your research project, please refer to the Research Ethics website to complete the appropriate REB form.

All projects must submit a report to REB at least once per year. If involvement with human participants continues for longer than one year (e.g. you have not completed the objectives of the study and have not yet terminated contact with the participants, except for feedback of final results to participants), you must request an extension using the appropriate LU REB form. In all cases, please ensure that your research complies with Tri-Council Policy Statement (TCPS). Also please quote your REB file number on all future correspondence with the REB office.

Congratulations and best wishes in conducting your research.

Rosanna Langer, PHD, Chair, *Laurentian University Research Ethics Board*